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THE INDIAN

MANUAL OF HYGIENE

VOLUME I.

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SURVEY OFFICE, MADRAS.
1893

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Vide Vol. II Appendix I

THE INDIAN

MANUAL OF HYGIENE

BEING

KING'S MADRAS MANUAL OF HYGIENE

REVISED, REARRANGED AND IN GREAT PART REWRITTEN

BY

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INDIAN MEDICAL SERVICE

PROFESSOR OF HYGIENE, MADRAS MEDICAL COLLEGE

VOLUME I.

MADRAS

HIGGINBOTHAM AND CO

By Appointment in India to H.R.H. the Prince of Wales.

1894.

PREFACE.

To the medical officer but lately arrived in the tropics, one of the earliest and most important matters of concern is, naturally, the ascertaining of the special sources of information that exist upon Disease in India and its Prevention. Before he has been long resident in the country it must become evident to him that things in general are in many ways different from what they are in Great Britain, that he has to unlearn a little and to learn a great deal. It is not merely that the population is different from that of Great Britain but that it is composed of elements differing essentially in themselves; that some invariably wear one kind of dress and some another, and that by many clothing is looked upon as a luxury rather than a necessity; that to some the eating or even the thought of meat, especially beef, is pollution, whilst others have no objection to beef but look upon pork as a thing of abhorrence; that some eat little but rice all their days, whilst others rarely see rice; that some live in a climate in which the annual range of temperature is more than 100° F.,

whilst others spend their days in a climate with an annual temperature range of about 25° F. Clearly, then, he has much to study and much to see ere he can gain even a rough and incomplete idea of the social conditions and vital surroundings, the demography, in fact, of the 300,000,000 inhabitants of the Indian Empire.

Further, a little reflection and observation will soon convince him that of the numerous subjects he has studied there are some which are identical in all important respects with what he has already learnt, *e.g.*, Anatomy, Physiology, Obstetrics, Materia Medica, etc., whilst others, typically Surgery and Medicine, retain their essential features but require important alterations and additions in many points, and, finally, that there are three great subjects, *viz.*, Pathology, Medical Jurisprudence and Hygiene, which differ so much in India and present so many entirely new features that he is almost helpless without special works to guide him. In the case of Medical Jurisprudence there need be no difficulty, for there are in existence two standard books in which is contained all that is necessary*. In addition, there are several excellent books dealing with the Practice of Medicine and its various subdivisions, such as Fevers. There is, unfortunately, no text book of Indian Surgery, as yet, though there are many excellent monographs on its special branches. Still more remarkable and regretable, however, is the non-existence of standard works upon either Indian

* *A text book of Med. Jur. for India*, by Bde.-Surgeon Lt.-Colonel J. B. Lyon, C.I.E., F.C.S., F.I.C., and *Med. Jur. for India*, by the late Norman Chevers. The latter is now out of print, but a new edition is in preparation.

Pathology or Hygiene. It seems almost incredible that it should be so after years of British occupation and generations of medical officers, including men of world-wide fame and unsurpassed ability. It is not here intended to discuss the reasons for such a state of matters, but some of them will be alluded to incidentally hereafter.

Though, as has been said, there is no standard work on hygiene in India, there have been written three books of moderate size and completeness, and many elementary books and pamphlets dealing superficially with the subject or in a very simple form for the use of schools. The oldest work of any size is that by Sir William Moore, entitled 'Health in the Tropics; or Sanitary Art Applied to Europeans in India,'* an excellent work, which serves to illustrate, as do Miss Nightingale's writings, how many years ahead of sanitary reform a sanitary reformer may be, and how slowly is the lesson of cleanliness appreciated or applied. In 1875 was published 'The Madras Manual of Hygiene', compiled under the orders of Government, by Surgeon-Major H. King, the first and only attempt at a systematic text book for students of medicine and others. In 1880 the second edition of this book was published. In 1888 Mr. J. A. Jones, M.I.C.E., at the present time Sanitary Engineer to the Government of Madras, published, under official approval, his well-known 'Manual for District and Municipal Boards', which contains a large amount of information relative to sanitary work and construction. Finally, in 1889

* Published by Churchill, London, 1862.

the late talented and much-lamented Surgeon-Major C. J. McNally, formerly Professor of Hygiene at the Madras Medical College and at that time Acting Deputy Sanitary Commissioner, brought out his excellent book, 'The Elements of Sanitary Science: a Hand-book for District, Municipal, Local, Medical and Sanitary Officers, Members of Local Boards and Municipal Councils and Others.' In many ways this book is the best yet published in India on the subject, and is very well suited to all who wish to gain a clear idea of the leading facts and principles of hygiene, but whose scientific and technical knowledge is limited. It is by no means, however, comprehensive or systematic, and makes no claim to be considered as a text book for advanced students, medical officers and others. Of the smaller works, the more important are the clear and thoughtful *brochure* of Surgeon-Major S. J. Thomson, at present Deputy Sanitary Commissioner, N. W. Provinces, 'Sanitary Principles, more especially as applied to India,'* the 'Sanitary Primer' by Surgeon-General J. M. Cunningham, and, quite lately, the Sanitary Primers for Schools by Surgeon-Captains A. E. Roberts and P. Hehir. In addition, several excellent pamphlets on 'Water,' 'Precautions against Cholera,' etc., have been issued.†

It was originally intended by the author to write a small and compact text book, principally for the use of students of medicine, to whom many of the terms and examples contained in English works are unintelligible. At the same time material was to

* Brown & Co., Calcutta, 1883.

† *e.g.* 'Cholera and Water in India,' by Surgeon-General M. C. Furnell, M.D., C.I.E., and 'Simple Sanitary Rules,' by Surgeon-Major W. G. King, M.B., etc., etc.

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be sought for, gathered and arranged, for a large and, as far as possible, complete Manual of Indian Hygiene, to be issued in the course of several years. The second edition of the Madras Manual of Hygiene being out of print, Messrs. Higginbotham and Co., in 1892, applied for and obtained permission to reissue a new and revised edition, as a purely private publication, and at their request the present writer undertook the work. At first it was believed that thorough revision and a few alterations were all that were necessary, but, as the work proceeded, it soon became clear that most of the information was out of date and that the book was in other ways unsuitable for present requirements. It was therefore determined to rearrange, rewrite and enlarge it, to illustrate it, where necessary, and to make it applicable to the whole of India.

Owing to its being the first work of its kind there has been great trouble in even ascertaining the various sources of information. It would have been both interesting and instructive to have illustrated each individual point with examples drawn from local sources, but besides the fact that this would have rendered the present work too bulky, there remains the important condition of its practical impossibility owing to the limitation of all sanitary officials to certain particular presidencies or districts; the one exception being the Surgeon-General with the Government of India, who, obviously, could not possibly undertake the particular work required. Before any text book of Indian hygiene can have the fully representative character and intrinsic value it should possess, there must be available the records

and observations of a capable and carefully-selected sanitary officer who, untrammelled by official burdens or restrictions, has travelled through the length and breadth of India; who has personally inspected the numerous sanitary systems and institutions; who has spent days in the bazaars and streets of the towns and villages, and has made himself familiar with the customs, appearances, food supplies, habitations, etc., of the various peoples; who has studied the important influence of climatic and physical surroundings in modifying their health and general well-being; and whose opinion may thereby carry the weight and conviction his great experience would justify. Certain it is that work thus carried out, and knowledge thus gained, if embodied in a text book or separately issued in explanation and amplification of the same, would very materially help the onward progress of hygiene in India and be of immense use to all local workers in the field of sanitary science. It is sometimes asserted that nothing of any value is to be thus gained, some boldly declaring that the climate, customs, food supply, etc., are practically the same for all India, whilst others declare that they are so different in different places that no good can come of an attempt at a general survey. To both classes the answer is—let the experiment be fairly tried once; the expense would be very small, the results, it is not doubted, of great and lasting importance. The author has many times sought in vain for a comprehensive and detailed survey by one worker as here sketched out, the need of which becomes at once apparent to any one desiring systematic information on this vast subject. But for such a task the individual selected

must not only possess a wide general knowledge, coupled with the training of a specialist in hygiene; he must be ready to go into the highways and hedges, to bear the burden and heat of the day, and, above all, be in true and thorough sympathy with his fellow-subjects, the toiling and ailing millions of India.

In the absence of any systematic text book on Indian hygiene it is evident that the want of the same is felt not merely by one class of persons but by all concerned with the subject. So far as possible, then, the aim of the writer has been to supply a book which will be neither too superficial nor too comprehensive, and which, whilst containing all, and more, than is required by students of medicine, will yet serve as a useful guide and means of information to military and civil medical officers, assistant surgeons, candidates for a degree in sanitary science, and others. It is obvious, of course, that anyone holding a purely sanitary appointment should be acquainted with all the original books, memoirs, reports, etc., dealing directly or indirectly with the subject, but this, owing to the isolation of Indian stations and the want of scientific libraries, is by no means easy. It is intended, therefore, to insert at the end of the second volume a short descriptive list of the chief books and other publications connected with modern, and especially Indian, hygiene, and it is further intended, if found feasible, to separately publish an as nearly as possible complete index or digest* of the numerous memoirs, papers, reports, etc., on hygiene and sanitation which have appeared in India,

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* Now in preparation.

with the exception of those dealing purely with statistics.

If to any reader it should appear that in places one subject receives disproportionately full treatment, to the detriment of others, let him remember the varied nature of the audience for whom the book is written and the extreme difficulty of pleasing all alike. Let him remember also that what may seem a simple and unnecessary explanation to one who has studied hygiene in England, may be difficult and new to an Indian student, and *vice versâ*, allusions may be made to habits and customs with which the student has been familiar since his youth, but which are novel to the fresh arrival from Europe. And there is still another important aspect of this question. If the teaching of hygiene to students is to bear any fruit in their after career it is necessary that they should be presented with a broad and attractive view of the subject. How common it is to meet medical officers upon whom the sole effect of their brief and purely lecture-room training has been the strengthening of their opinion that hygiene is a synonym for sanitation, and that sanitation is summed up as the "looking after drains and bad smells, and all that sort of thing." It should, therefore, be clearly brought home to the student, in order for the prevention of so limited a conception, that hygiene is a science which has only of late years become a science, that in its application it is termed sanitation, that it requires a most varied and extensive knowledge, that it is intimately connected with other sciences that bear upon the moral and physical health of mankind, and that its good effects are soon

felt and increase in geometrical ratio. True, mistakes have occurred and will occur from obstinacy, timidity or misguided enthusiasm, but the central fact remains that on moral, political, financial and purely personal grounds, the study of hygiene and the spread and progress of sanitation amongst the people are to be earnestly desired and encouraged. It is hoped, therefore, that the student who honestly peruses the contents of this book may not only gain therefrom the special information necessary for examination purposes, but may be led to see the wide, and at the same time intimate, relation of hygiene to other important matters, and may also be enabled to realise, as noted above, the essentially practical nature of the subject.

One great difficulty in inducing students to take a real and lasting interest in hygiene is the fact that, as yet, there are extremely few, if any, purely sanitary posts open to them. It is only a matter of time till the larger towns* have each their health officer, and for such posts there are a few men to be found in the Indian Medical Schools who have every qualification save the special training after graduation.†

Year by year the duties of District Medical Officers are increasing in number and complexity, and some day it will become thoroughly apparent that one man cannot be the sanitary officer of a large town, sanitary officer of a district of 10,000 square

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* According to the latest census (1891) there are 30 towns with a population of over 100,000, 48 with a population of over 50,000, and 149 with a population of over 20,000.

† Even now there is one medical graduate trying, in the absence of all proper facilities, to take the L. San. Sc. degree of the Madras University, and others are writing or have written to know how it can be managed.

miles or more, the medical officer in *executive* charge of one or more hospitals, and possibly of a jail as well, and in *administrative* charge of numerous smaller hospitals, dispensaries, vaccination stations, etc., etc., without some portion of his work receiving but very nominal attention.* Such a state of matters is good neither for the official nor for the district in which his sphere of labour lies. If sanitation is to make solid progress in India, it is necessary either to appoint special and purely sanitary officials, who shall be resident in their districts, or to largely increase the number of District Medical Officers.† The statement that in the present state of affairs occasional inspections by the District Medical Officer, with an annual or biannual visit of the Sanitary Commissioner or his Deputy, is all that is required, is untrue and shows complete failure to realise the

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* The point that seems to require special emphasis is the fact that so large a portion of *medical* work is executive and not merely administrative, and that to an amount of the former which would be considered ample work for an ordinary practitioner in England, is added a very large amount of administrative labour in connection with returns, reports, communications from all other departments, inspections, etc., etc. In addition, most people fail to realise the peculiarly wearing effect of the continuous and unremitting responsibility inseparable from the conscientious treatment of the sick, and the severity of the punishment invariably meted out for any real or supposed carelessness in such work.

† "It may be urged that the civil surgeon is a stationary officer, or at any rate is supposed to be so, and will not be able to visit personally all the villages of the district; it will be taking him away from his legitimate work of treating the sick in the station [which is just what does happen continually under present arrangements]. Suggesting rules and measures in writing from his office, he may do; but travelling into the district from village to village will be practically a physical impossibility, having regard to his urgent daily station work, as also to the extent of the district. That is a reasonable argument and a real difficulty. Then have a regular sanitary office for each collectorate distinct from the deputy sanitary commissioner." *v.* Trans. VIIth San. Sci. Cong., Vol. XI., p. 117. In England, this matter, *viz.*, the appointment of Medical Officers of Health, absolutely distinct from ordinary practitioners and debarred from practice, has at length, after years of fighting and much waste of time and money, been finally settled in the affirmative, with corresponding and speedy benefit to the health of the general public.

necessity for continuous supervision and attention to details. By all means introduce pure water supplies and good drainage schemes into the larger towns as rapidly as possible. They are of inestimable value, but they do not constitute the sanitation of India.

The whole subject of the expansion and development of sanitary science that must needs take place in India is considered in several papers contributed to the Seventh International Sanitary Congress.* Two points are of especial importance, the spread of a knowledge of sanitary principles and practice, and the education of purely sanitary officials. With reference, firstly, to the latter point, it may, possibly, be necessary, or strongly advisable, to send selected engineering students to Europe, as advocated by many ; it is certainly quite unnecessary to send medical graduates there. There is nothing now wanting in Madras for the complete instruction and training of sanitary officers save time and the proper facilities. The means are there,† from a laboratory of hygiene completely equipped, far more so than many in England, to a town presenting almost every possible sanitary or insanitary feature of interest. Given properly-arranged courses on the special subjects, practical and theoretical, a good student after seeing, perhaps, the other presidency towns, would be in all points fitted to take his L. San. Sc. degree and to become the health officer of a town or district—always supposing that he possessed the high qualities essential to success in this profession. It is not asserted that

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* *v.* Vol. XI of the Transactions.

† Save a Museum of Hygiene, the building of which, however, is being considered.

"trained Indian sanitarians will [or should for many years] perform the duties which now devolve upon the higher sanitary officers of the Presidency." "They have not," says one writer,* "the same education [as English students], though it may be good of its kind and very creditable, considering the educational and instructional appliances of Indian Medical Colleges."* * * "The Indian student, to be a practical scientific sanitarian, will have to be practically educated to appreciate the practical difficulties of carrying out sanitary measures." This question of furnishing trained sanitary officers to the larger towns and to the districts is of such importance and, though its solution in the affirmative is only a matter of time, is likely to meet with so much opposition on financial grounds, that it is extremely important to consider it from the stand-point of expense and to see whether the Indian student does really labour under such disabilities as compared with the same class in England. The writer can only speak of Madras and, so far as Madras is concerned, he states most emphatically that it is not so. For years the course of lectures in hygiene delivered to M.B., L.M.&S., and Government 'warrant grade pupils,' has been longer and more complete than that required for M.B. Students at the British universities. Instead of three months with lectures on alternate days of the week, the course at Madras Medical College continues for six months, during which there are, on the average, more than sixty meetings, including over fifty lectures, eight oral and two

* Surgeon-Major K. R. Kirtikar, I. M. S., v. Trans. VIIth San. Sci. Cong., Vol. XI.

written examinations. The subject is far more fully gone into than at most English Colleges, and it is impossible for a student to take his degree without attending such a course, whereas, until quite lately, there were many officers to whom the subject of hygiene was a closed book before attending the course on Military Hygiene at Netley. For any one intending to become a specialist in research it is certainly, and most regretably, still necessary for him to proceed to Europe. But for the thorough post graduate training of sanitary officers, Madras, as before stated, possesses everything that is necessary and, given proper development of the facilities available, there is not the slightest necessity to go to the expense of sending home those intended for future sanitary officers. The average Indian medical student or graduate would certainly not make a good sanitary officer, for various reasons, but there are quite enough exceptional men who combine an intimate knowledge of the country and its customs with the high qualities necessary for the sanitarian.

As regards the other great sanitary need of India already alluded to, *viz.*, the popularisation of an elementary knowledge of hygiene, it is pleasing to see that the question is being earnestly taken up by the educated natives of India themselves, backed by the able advocacy and exertions of Miss Florence Nightingale and others.* There is no doubt that a great deal could be at once accomplished in this direction by means of lectures illustrated by diagrams, lantern slides, and practical demonstrations, but at present no one who has the requisite skill and know-

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* *v.* Several papers in Trans. viith San. Sci. Cong., Vol. XI.

ledge has also the necessary leisure. Such lectures, adapted to the capacity of the various audiences, would naturally form part of the work of the special Sanitary Officers who must ultimately be appointed for all large towns and districts, in place of the already over-worked District Medical Officers.

So far the discussion has been limited purely to the question of the sanitary needs of Indian towns and districts. But what about the work of enquiry into the various disease-scourges of this great country? What about the patient and careful study of the countless unsolved problems which confront all engaged in sanitary work in India? What about the systematic investigation of the food-stuffs, as to composition, purity, etc., upon which 300,000,000 persons depend for food? What about malaria, which kills its millions and disables its tens of millions? What about cholera, elephantiasis, beri-beri, enteric fever, dysentery, jail-diarrhœa, anæmia and the whole gamut of Indian disease? What about the study of Hygiene in fact? Nothing! or next to nothing, save what a few earnest and unthanked workers are able to accomplish in the intervals of arduous routine duties. In the whole of the Indian Empire not one institution where half-a-dozen trained investigators are constantly engaged in studying the questions of disease causation and prevention. Everything is considered of greater importance than this. *One* bacteriologist and the promise of *one* officer if the public subscribe the money for a Pasteur Institute! The British race is avowedly afraid of the word scientific because, owing to a total misconception, 'science' is supposed never to pay. Even by

many medical officers, who have been or are 'sanitary officers' as well, the pursuit of scientific investigation is looked upon as something quite apart from ordinary teaching and ordinary sanitary work. Disregarding for the present the inaccuracy of this view, it must be pointed out that they also forget the fact that nothing is so stimulating to the student and nothing is so qualified to make him an earnest, useful man in after-life as the sight of others engaged in enquiries into the actual causes of disease. All that he learns in the wards of a hospital he can read of in his books, but there is something new and strange in a research laboratory, enabling him to realise how little is known, how much remains to be done, and that he himself, like the workers he saw, may hereafter do something, not merely to lessen misery and relieve the sick, but to break the power of disease. As to the question 'Does it pay'? there are signs that the British public is beginning to find out for themselves, as they have gradually found out in the case of sanitation, that it certainly *does* pay. Once they realise this, there is no fear for the future and then, instead of India having no Hygienic Institute and every European country one or two, India will probably have one in every presidency and independent province till there are as many as in all Europe.* At present the small French Colony of

* Nothing lately has given the writer greater pleasure than the reading of a review of the *Official Catalogue of the German Empire*, at the Chicago Exhibition (*v. Nature*, 22nd June, 1893), in which is set forth the enormous industries which have grown up in that country as the direct result of pure scientific investigation. "Side by side with the military forces, the scientific forces of the country have been carefully and patiently organised. At the instigation of Liebig, great state laboratories for pure scientific research were erected all over the country, and from these have issued an army of highly-trained workers." * * * "Firms with 40 workmen sometimes employ as many as 5 or 6 chemists and three great colour firms

Tonkin is better equipped in this respect than the Indian Empire. It is frequently urged by the timid or sceptical that quite as much is being done for Indian sanitation as is advisable in the present state of education. Without for one moment admitting the truth of such assertion, it may be pointed out that the study of hygiene is not subject to any such disadvantage, and since the refusal to do more is ascribed purely to a desire not to 'push matters,' it should be pointed out that now is the time to pursue the study of hygiene, to elucidate the causation and means of prevention of disease, so that when public opinion reaches the wished-for degree of development, advantage may be taken at once of the discoveries of the workers in hygiene.*

With the exception, then, of the three presidency towns, the purely sanitary workers in India are a mere handful, willing and capable enough, but unable to work miracles and to multiply themselves

employ 178." * * * "In our own humble opinion the days of *laissez faire* have gone never to return, and the time has come when the Government of the country, backed by the country, must take as is the case in Germany—a larger share than it has done hitherto in the systematic organisation of our scientific and industrial forces." It should be noted also that it is not merely in chemical products that Germany is taking or has taken the lead, but also in scientific instruments, engraving, hardware and countless other directions. Truly we are paying dearly for our slavish fear of 'science' and of anything which does not 'pay' at once.

* The utter absence of any true research work in hygiene in India, is rendered painfully evident by the fact that amongst the whole of the papers contributed to the Indian Section of the Seventh International Congress of Hygiene and Demography, there was not one single paper giving the results of scientific investigation into the problems of Indian Hygiene. This, of course, is not due to the want of trained scientists amongst the officers of the Indian Medical Service, for there are many such; but the facilities and encouragement for the work are so entirely wanting that it is almost impossible for any one to attempt it. So also there was not a single scientific paper from Indian Engineers. Why? It has been left to a private individual—Mr. John Wallace, C.E.,—to publish the first work on Sanitary Engineering in India. So little is the term hygiene understood, even by some medical officers, that a remark of the author's as to the absence of hygienic research in India, was understood to mean that no one in India knew anything about sanitation!

indefinitely. Madras, with an area of 141,189 miles, in which are 214 towns, 56,867 villages, and a population of 35,630,440 persons, possesses one Sanitary Commissioner and one Deputy Sanitary Commissioner, whilst the District Medical Officers are supposed, in their rambles of inspection over the 10,000 square miles or more of country which is under their charge, to exercise their additional function of 'Sanitary Officers.' As to the *value* of the work done under such conditions of hurried and intermittent inspection let the Reports of the Sanitary Commissioners issued year after year testify. The amount of routine work is enormous, the tables are endless, but the nett results are small indeed compared with what they would be had each district its own sanitary officer constantly at work amongst its towns and villages, stimulating the indolent, helping those in doubt, lecturing, etc., etc., and evidencing, by his presence, the keen interest of the State in the salvation and betterment of the lives of its subjects.

Of the work done by past and present generations of Indian sanitary officials, in the face of much opposition and scepticism, no one has or can have a higher opinion than the writer. There can be few things more disheartening than the sanitary charge of a district in which the inhabitants are sunk in apathy, surrounded by filth, and kept, by grinding poverty, on the borderland of starvation; where the European officials too often say "What's the use, you *can't* make these people clean"! and the educated natives say, or imply, that it is isn't worth while doing so if one could, for there are always

enough of these people to till the land and do the manual labour, which is all they are good for; where in reply to complaints to the higher authorities, it is acknowledged, indirectly, that one is expected to make bricks without straw, but that in the present dearth of the latter article the sanitary department cannot possibly receive more, and so on. Truly it needs great faith and endurance to go on steadily, as many have done, in the face of all this, and to accomplish as much, or as little, as is permitted. As a result of the present system, the District Medical Officers in India fall into two divisions—those who by habit and training are accomplished and earnest sanitarians, and those who are not so, either from want of interest or from a perfectly legitimate desire to devote their time and energies to the over abundance of purely medical and surgical work lying to their hands.* Surely it is time that the idea that a medical officer is *ipso facto* capable or desirous of the duties of sanitary officer as well, was given up,

* With reference to this point, Sir Mountstuart Grant Duff, in his opening address as Chairman of the Indian Section, at the Seventh International Congress of Hygiene and Demography, made the following remarks. "We made, in my time [as Governor of Madras], the civil surgeon of each district a sanitary officer, and imposed upon him the duty of advising the presidents of municipalities and local fund boards in every thing that relates to medical and sanitary affairs; providing him at the same time with a second in command to undertake some of his former duties. I hope that change is working well." That change, so far as sanitation is concerned, is working well just where the district medical officer takes a keen personal interest in the subject, and in these cases it is equally certain that the purely medical work must suffer. The 'second in command' was an absolutely necessary addition owing to continued expansion of the executive and administrative medical duties of the districts, and cannot be regarded as a means by which the medical officer is perforce transformed into a trained and willing sanitary officer. Once more, a man cannot possibly look after the entire medical and sanitary work of a district of many thousand square miles. This point is strongly insisted on by Surgeon-Major Kirtikar in his paper, *Our Sanitary Wants in the Bombay Presidency*, communicated to the VIIth San. Sci. Congress, and, indeed, its urgent claim to immediate attention must impress all who have the sanitary and medical welfare of India at heart.

and the acknowledgment honestly made that the two classes should be kept distinct, and that proof of special training and aptitude will invariably be required from those selected for the latter class of appointments. Of the leading sanitary officials in India, one thoroughly competent to speak* has lately said, "His extensive connection with various sanitary workers in this country and the continent had brought him in contact with a large number of medical men, but he could say, without hesitation, that the Sanitary Commissioners and Medical officers of Health of India were most devoted to the prosecution of sanitary work, and possessed a vast amount of information as to the causes and the prevention of disease in that country, and that they would compare favourably with like officers in other countries." It is not the men so much as the system which is at fault.

It is a commonly observable, though much-to-be-regretted, fact that long residence in India seems to blunt the æsthetic sense of many officials, medical and otherwise, so that the filthy smells and unspeakably offensive sights common to towns in the tropics no longer cause a feeling of active disgust within the observer. Years of daily contact with a people, the mass of whom, rich and poor, educated and uneducated, regard such matters with perfect composure or indifference, have inoculated these officers with the fatalistic virus to such a degree that they have even been known to imply by their remarks that the attempt to sanitate Indian towns

* Mr. Baldwin Latham, M.I.C.E., of world-wide fame and experience as a Sanitary Engineer.

and their inhabitants is a mistake, an interference with the laws of Nature! Others, it must be confessed, never started even with any enthusiasm for the true cleanliness of men and cities. Their being of British origin entitled them to the credit of a love of cleanliness for its own sake, but their subsequent lack of interest in the matter, and entire acquiescence in the insanitary conditions around them, have made it obvious that their cleanliness was only superficial, and the result of a favourable environment in early life. If there is one thing in which the British dweller in India should set a constant good example, it is in this matter of scrupulous cleanliness in person *and surroundings*, even at the cost of considerable trouble and a little expense.* The plea of ignorance is not allowable; in this matter ignorance is culpable. It is well to remove the beams in our own eyes, and then shall we see clearly to cast out the motes in those of our brethren.

The present book may be said to retain but few of its original features. A considerable amount of matter has been omitted or altered, and a very large amount added. The introduction is entirely new and is intended, primarily, to give the student a bird's eye view of the subject, and to enable him to trace the gradual evolution of hygiene from the simple idea of self-preservation, up to its modern high degree of development and organisation, under which the State orders and controls the measures to

* The mere fact that in a presidency town, like Madras, there is no proper market in the year of grace 1893, and that the English residents, as a class, are still content to allow their daily food to be exposed to chance contamination from loathsome practices and impurities, betokens a grievous amount of 'tropical languor,' or an extraordinary degree of callousness.

be adopted for the Public Health, and in doing so enlists the aid of its educated and humane subjects, either individually or in theform of local and municipal bodies.

In the First Chapter the original arrangement has been slightly altered and the whole carefully revised; the Second and Third Chapters are largely altered and added to; the Fourth, Fifth and Sixth Chapters, with the exception of a few paragraphs, are entirely new. In the Second Volume by far the greater part of the book will be new. The numerous tables and formulæ for calculating the humidity, atmospheric pressure, etc., formerly given in the Madras Manual, have been omitted, both because they were chiefly applicable to Madras only and because special tables, issued officially by the Government of India, are now available for any one wishing to pursue the subject further. It is hoped that the tabular statements of Indian climates, the source of which is acknowledged below, will prove of general interest and encourage the reader to peruse the original work in which they are contained along with many others. A very large number of works have been consulted in the preparation of this book, including those of Wilson, Murphy and Stevenson, E. A. Parkes, L. Parkes, Whitelegge, Galton, Simon, Hirsch, Boulnois, Denton, Crimp, Sykes, Longstaff, Newsholme, Creighton, Kingsley, Mill, Scott, Burdett, Miss Nightingale, and many others too numerous to mention, and, in addition, many works relating to India, by McNally, Moore, Jones, Clark, Wallace, Blandford, Medlicott and Blandford, Fayrer, etc., and numerous reports and memoirs.

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unremitting official duties. It is hoped that all such will be pointed out, and the author assures his readers that he is only too anxious to receive advice, suggestions, and friendly criticism from all who are engaged in sanitary work. He also hopes that to no one has offence been given, as certainly none was intended, but in writing on matters sanitary the importance of the issues involved renders it necessary that the language shall be clear and to the point. Lastly, it should be remembered that, the work being entirely unofficial, the opinions expressed are to be regarded as purely private. The difficulties connected with the publication, and especially the illustration, of a book in India are so great, that those at least who have essayed a similar venture will fully understand and readily pardon all shortcomings in this direction.

HYGIENE LABORATORY,
MADRAS MEDICAL COLLEGE.
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ERRATA ET CORRIGENDA.

VOLUME I.

Page 2, line 16, *for* 'names' *read* 'name.'

„ 7, „ 6, „ 'of' *read* 'or.'

„ 19, „ 20, „ 'retatively' *read* 'relatively.'

„ 32, „ 9 & 10, *delete* 'per head.'

„ 41, „ 9, *for* 'Ellinson's' *read* 'Ellison's

„ 57, „ 11, „ 'follows' *read* 'follow.'

„ 59, bottom line, *for* 'sued' *read* 'used.'

„ 68, line 7, *for* '15°.' *read* '15°.C.'

„ 88, „ 11, „ 'calcare' *read* 'calcaire.'

„ „ „ 15, „ 'fruit' *read* 'seed,'

„ 119, lines 16 & 17, *transpose* 'warmer' and 'colder.'

„ 120, line 3, *footnote* *, *for* 'previous' *read* 'pervious.'

„ 122, „ 2 from bottom, *insert* '(4) Cholera;'

„ 137, *footnote, for* 'Wilson' *read* 'Wilson's.'

„ 138, lines 15 & 20, *for* 'deoderant' *read* 'deodorant.'

„ 157, *Transpose* the sentences beginning, respectively, "The former are often called" etc., and "Careful Distinction" etc.

Page 171, line 24, *delete* '(*v.* pl. ix.).'

,, 179, *footnote* †, *for* 'pl. vii.' *read* 'pl. ix.'

,, 192, line 24, *delete* 'to.'

,, 214, ,, 6 from bottom, *for* 'temporary' *read* 'temporarily.'

,, 216, *Footnote* †, line 6 from bottom, *for* 'Chindevin *read* 'Chindwin.'

,, 226, line 4, *for* 'deoderant' *read* 'deodorant.'

,, 301, *foot note* †, *for* 'p.' *read* 'p. 288.'

, 303, ,, †, ,, 'p.' *read*, p. 293.'

,, 349, line 3 from bottom, *for* 'a five hundredth' *read* 'five hundredths.'

,, ,, ,, 1 ,, ,, 'a two thousandth' *read* 'two thousandths.'

,, 351, line 3, *for* 'pl. xix.' *read* 'pl. xvi.'

,, 368, ,, 12, ,, 'per hour' ,, 'respectively.'

,, 406, ,, 7, ,, 'malaria' ,, 'malarial.'

INTRODUCTION.

Non est vivere, sed valere, vita, wrote the Roman poet* many years ago—"Not merely to live, but to be well, that is life"—for without good health, living is mere existence and the capacity for true enjoyment extremely limited. Though many realise this important fact in its more obvious sense, as evidenced by the common form of greeting, "I hope you are quite well?" it is only those who have devoted special thought and attention to the subject that are enabled to grasp the full significance and meaning of the phrase 'good health.'

From such a stand-point, the whole of the human race might be classified or arranged under two headings—The Healthy and the Unhealthy. In the latter class would come all who are not possessed of the *mens sana in corpore sano,* the healthy mind in a healthy body, and that this would include the larger portion of mankind there is little doubt. Now, the aim of the hygienist, put shortly, is to so influence the vital conditions and environment of the living amongst men, as to bring about the transfer of as large a number as possible from the latter to the former class. Note, also, that whilst doing this, he ensures that the coming generation, as the offspring of healthier parents and the inheritors of improved conditions of life, shall go to swell the

* Martial.

numbers of the truly healthy, to whom life will, in the best sense, prove enjoyable, and not a weariness of the flesh.

This view is sometimes disputed, and it is argued that one effect of improved hygiene is to keep alive the weakly and diseased who would otherwise have died early, these in turn propagating a puny and unhealthy offspring: an artificial and unwarrantable interference, so to speak, with the natural laws resulting in the 'survival of the fittest.' This rather plausible fallacy will be disposed of later on.

Having defined, in very general terms, the scope of hygienic reform, it remains to go a little more into detail as to the origin of this science—for such it is—and as to what was originally indicated by the word 'hygiene,' compared with what is now, and in the future will be, included under this extremely comprehensive title. In its simplest meaning it signifies 'health' and is derived from the Greek word ὑγίεια (Hygieia), which was the name given to the Goddess supposed to preside over the bodily well-being of mankind. Amongst all nations not advanced in the scale of civilisation the belief is strongly held that disease is simply the concrete expression of the anger of offended or evil deities. This belief is naturally fostered by the priests of the various religions, who find therein a means of filling their coffers and reducing the supplicants to a proper degree of submission. It is, in truth, one of their most powerful weapons, and is used in many ways, for purposes of offence or merely of defence. Thus, amongst the very ignorant and superstitious, this belief forms a most convenient way of extorting money or of exciting fear, whilst with the more enlightened, whom the priest is unable to threaten directly with plagues and other discomforts if they do not obey his commands, advantage is taken of an epidemic of disease or of a prolonged drought to indicate the evident displeasure of the Deity; the profit accruing from such a proceeding being a demonstration of the superior perception of the feelings and wishes of the Supreme Being possessed by the priestly

adviser.* In the minds of some there thus arises an extraordinary confusion of ideas, occasioned, on the one hand, by the knowledge resulting from practical experience that certain acts will induce certain diseases, whilst on the other hand, illnesses of an obscure and insidious character are firmly believed to be the result of Divine displeasure. In proportion, however, as the mode of origin and intimate nature of the various diseases to which the human frame is liable have been, bit by bit, and one by one, demonstrated, so has the education of mankind progressed steadily, till many thousands among the enlightened of the nations have been brought to understand clearly that disease, while partly due to the mortal nature of the human body, is also largely due to the direct violation, through ignorance or otherwise, of the simplest laws of health. This may seem a small matter to those educated in a country like England, but in India its sufficient recognition by the people is nothing less than the foundation which must be laid ere any scheme for the prevention of disease can be satisfactorily carried out on the large scale. In the education of the young there is no matter of greater importance than the inculcation of the general methods by which diseases arise, and of the simple rules relating to bodily health, cleanliness, purity of air and water, etc., by which the occurrence of the former can be largely prevented.

* "That the Deity is normally absent, and not present; that he works on the world by interference and not by continuous laws; that it is the privilege of the priesthood to assign causes for these "judgments" and "visitations" of the Almighty, and to tell mankind why he is angry with them, and has broken the laws of nature to punish them—this, in every age, has seemed to the majority of priests a doctrine to be defended at all hazards; for without it, so they hold, their occupation were gone at once". Written thirty-five years ago by Charles Kingsley, a clergyman of the church of England, at a period when sanitary reform was looked at askance by the ultra-religious and viewed as a foolhardy interference with the workings of the Creator. All honour then to the 'priest' and man who, in the largeness of his humanity, did not hesitate to say what had to be said in no uncertain voice. Since then there has been truly a wonderful change, and no body of men now realises more thoroughly than the clergymen of the Established Church of England the power of clean and healthy surroundings to raise a man to a higher level—bodily, mentally and spiritually. It would be well for India could her own leaders, spiritual or otherwise, be brought to tell the truth in the same outspoken fashion.

Looking back on the history of the nations which have in turn led the civilisation of the world it will be found that there are invariably two points which stand out clearly. Firstly, the value of personal cleanliness was understood by the learned and wealthy classes and was practised by them, but it was chiefly a selfish knowledge, made use of for their personal safety and comfort, whilst all beneath them socially were allowed to exist in a condition infinitely inferior to that of the dumb animals belonging to their masters. Amongst the Egyptians, Medes and Persians, the priests and upper classes used friction and inunction of the body, abstained from certain kinds of food at specified seasons, practised gymnastic exercises, wore linen as being the cleanliest covering for the body, and attempted during epidemics to purify the air by fumigations. Secondly, in addition to this attention to personal cleanliness, was the fervent belief of all, from the highest to the lowest, that epidemics were visitations of the Divine anger, and being so, were to be subdued by endless propitiatory prayers and offerings. Amongst the Jews the same ideas prevailed to a large extent, but their priests had a clearly defined code of laws and regulations,* which will repay study by the thoughtful student, and is especially interesting as being the earliest known collection of rules relating to general sanitation. Their regulations dealt with the leprosy (so-called) of men, houses and clothing, with bathing, pollutions, the marriage of near relations, the situations of cemeteries, the isolation of the sick and the cleansing of vessels employed by them, the nature and mode of preparation of animal and other food, the disposal of excreta, etc. Many hundreds of years later, the careful observance of these rules by the conservative Jews, saved countless of their lives during the dread pestilences of the middle ages, whilst those around them were dying by thousands.

* Contained in the book of Leviticus, in the Bible. "It corresponds to the reality, in both the actual and chronological points of view, to consider the Jews (under Moses) as the creators of the science of Public Hygiene". Baas, *op. cit.*

To the fact that in their early days the Greeks and Romans lived up to the ideal of "plain living and high thinking" inculcated by the best of their philosophers, was due much of their success in all things, from bodily supremacy to the production of many of the world's masterpieces in philosophy, poetry and art. In later times, when luxury and immorality had first corrupted the Greeks and afterwards had sapped alike the health and independence of their Roman imitators, they became a fitting prey at once to epidemic disease and to the hardy northern tribes they had previously held in check. The essentially practical nature of the Romans showed itself in the elaborate and costly works they executed for the conveyance of pure water to the city of Rome and for the carriage of their sewage to the river Tiber, works of which large portions still remain more or less intact. With them, also, the place of the Jewish Levite or priest was taken by the Ædile, a public functionary upon whom fell the duties connected with the sanitary inspection of drains, streets and buildings, of baths, of food, etc., and in whom a considerable degree of authority was vested. As is well known, they carried the construction and use of baths to a high degree of perfection; to too high a degree in fact, for these latter became, ultimately, a mere excuse for luxury and idleness; true hygiene was neglected, and the people were attacked again and again with epidemics of disease that devastated the population and laid them at the mercy of their foes.

Corresponding to the Greek goddess Hygieia, before alluded to, was the Roman Dea Salus but, like many other nations in whose religion polytheism is a prominent feature, they could manufacture a deity on the shortest notice. Whenever, therefore, any evil particularly troubled them, they speedily elevated it to the rank of a divinity and worshipped it. Such were the goddess of fever, Febris; of foul smells, Mephitis; of itch, Scabies; etc., and when their drains or *cloacæ* were more than usually offensive, they created a goddess, Cloacina, and worshipped her devoutly!

Indian students can doubtless furnish many local examples of the same practice for themselves.

From the early years of the Christian era onward to the end of the fifteenth century is embraced a period of history unique in many ways, but in none more so than in the extraordinary number and severity of the epidemics of disease, amounting, by their universal distribution in many cases, to pandemics. The information obtainable is exceedingly scanty and frequently unreliable, but enough is known with certainty to convince all who read that never before*, or since, in the history of the human race, has the neglect of the commonest details of personal cleanliness and public hygiene been so universal and complete and, as a consequence, been followed by such fearful and wholesale destruction of human beings.†

For the first ten centuries or so the sickness chiefly took the form of the so-called 'plagues,' to be followed later by the dire 'epidemics' of the later middle ages. Of these plagues there are many historical accounts extant, but it is impossible to give them in any detail. One such visitation, known as the Justinian Plague, occurred at the beginning of the 6th century A.D. and was considered, as usual, to be associated with numerous Divine portents and threatenings, such as earthquakes, comets, volcanic outbreaks, peculiar-coloured markings on houses and food‡, and many other signs. In the year 542 the plague, which originated in lower Egypt, spread up the Nile and from thence to Asia Minor. "Constantinople was speedily attacked and (according to the almost incredible accounts) in the time of its greatest severity 5,000,—10,000 human beings perished there daily. In the next year, however, the plague striding over Greece to the west reached Italy. In 545 it extended to Gaul,

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* So far, of course, as can be ascertained from historical records.

† For much that follows the author is largely indebted to the *History of Medicine* by Joh. H. Baas, M.D., as translated and enlarged by H. E. Handerson, M.A., M.D., of Cleveland, Ohio, U.S.A., to the excellent, though brief, historical summary in Dr. George Wilson's *Hand book of Hygiene*, and to Dr. Charles Creighton's *History of Epidemics in Great Britain*.

‡ Caused by the presence and growth of coloured fungi and micro-organisms.

and in 546 it reached the Rhine, whose bordering cities (at that time in the bloom of prosperity), from Bingen-over-Mayence, the Metropolis, to Schlettstadt, it depopulated with its ravages. After its first period of fifteen years (which it is said to have afterwards almost uniformly maintained), the disease became milder, though it did not entirely disappear, until in 558 it visited Constantinople for the second time, with horrors only heightened by comparison with its first assault. So fiercely did it rage that the towers upon the walls were unroofed, filled to the brim with corpses, and then again covered in, since hands were wanting to assist in their burial; while many of those who lent aid in this horrible labour of heaping up the dead fell down themselves and expired in the midst of their task. Thus new causes of death in the form of the horrible gases of decomposition were pent up, as it were, in these fearful store-houses. In other cases the dead were treated more judiciously and hygienically by sinking the corpses in the open sea with the aid of a ship specially appointed for that purpose, though some bodies were carried back by the waves to the shore—dreadful tokens of warning to those who yet survived. In this plague, however, the general imminence of death broke down all the barriers of custom and shame to such a degree that only the worst of mankind seem to have survived. In the year 565 this unprecedented plague visited Italy a second time so severely that the Romans could not advance against their enemies. For long years it endured, intermixed at the close with the small-pox, sweeping away in its devastating course the bloom of manhood and youth, and destroying the greater part of women, maidens and children in all the then known world. It loosened, too, almost all the rootlets of the ancient civilisation, so that the withered stem was able to maintain for centuries, only a feeble and sickly existence."*

* It is impossible to gain even an approximately correct idea of the mortality resulting from this great plague, but that it was enormous there is no doubt. Concerning this Justinian plague, Creighton has some pertinent remarks. "The historian Hallam includes a thousand years in the

From these early centuries onward the same state of things continued to a great extent. Civilisation and its resulting comforts may be said to have been limited to the very few who could afford them, but even in these cases it was but a superficial gloss. Their general mode of life and their personal habits alike were in the main filthy and coarse, far worse than those of many nations who preceded them in this world's history. Under the name of religion most extraordinary things were done, *e.g.*, the extremely meritorious and pious practice of kissing leprous ulcers. Immorality in its grossest forms was the rule and was a most fruitful cause of disease. In fact, that the "Middle Ages were socially and hygienically a most degraded period" will be very thoroughly realised by any earnest and unbiassed student of history.*

As to the factors which aided in spreading disease far and wide it is written, "The causes of this phenomenon were in part prolonged in their effect from the last ages of Antiquity. In this connection we must mention first of all the wandering and restless migration of peoples (including the Crusades) and of individuals. From this arose,

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mediæval period, from the invasion of France by Clovis to the invasion of Italy by Charles VIII., in 1494. We begin, he says, in darkness and calamity, and we break off as morning breathes upon us and the twilight reddens into the lustre of day. To the epidemiologist the mediæval period is rounded more definitely. At the one end comes the Great Plague in the reign of Justinian, and at the other end the Black Death. Those are the two greatest pestilences in recorded history; each has no parallel except in the other. They were in the march of events and should not be fixed upon as doing more than their share in shaping the course of history. But no single thing stands out more clearly as the stroke of fate in bringing the ancient civilization to an end than the vast depopulation and solitude made by the plague which came with the corn-ships from Egypt to Byzantium in the year 543; and nothing marks so definitely the emergence of Europe from the middle period of stagnation as the other depopulation and social upheaval made by the plague which came in the overland track of Genoese and Venetian traders from China in the year 1347. While many other influences were in the air to determine the oncoming and the offgoing of the middle darkness, those two world-wide pestilences were singular in their respective effects: of the one, we may say that it turned the key of the mediæval prison-house; and of the other, that it unlocked the door after eight hundred years."

* A statement, the truth of which is in no way controverted by the fact that amongst the rich or amongst those living in cloistered retirement it was by no means rare to find pure and high-souled devotion to the culture of religion, art, literature, or even to the claims of humanity.

gradually, complete insecurity of property with its lack of employment, idleness, and their result, imperfect cultivation of the land. The latter brought about a failure of crops, which again, united with the utter want of good roads and commercial facilities, * * * created dearth and famine, continual poverty, and generally insufficient, bad and coarse means of subsistence. Personal uncleanliness was the rule and the clothing worn, of leather or rough wool, was seldom changed day or night. Immoderate quantities of wine and strong ale were consumed, and gluttony and intemperance were prominent failings of the mediæval Britain. * * * The towns and villages were composed for the most part of hovels with mud walls and thatched roofs." The floors of the houses were unpaved, damp and usually covered with rushes underneath which lay the collected filth of ages. The streets were dark, narrow and tortuous and no attempt to pave or drain them was made. The dead, from whatever cause they died, were generally buried in vaults beneath the churches or in defective graves in the churchyards, which latter were situated inside the towns and villages. The small population on the other hand were scattered in slight hovels over wild woods, dreary wastes, and undrained marshes, so that ague and rheumatism were always rife amongst them, and in times of scarcity, etc., they were sure to suffer from famine. Famines indeed, were terribly common in the middle ages and alternated with the devastating plagues. It has been computed that from the 11th to the 15th century there were thirty-two great plagues, whilst famine occurred about every fourteen years. None but those of the strongest constitutions survived and the population remained almost stationary. Such were some of the evils which favoured not only the origin, but the wholesale and repeated spreading of the various pandemics.*

* The description of mediæval England, above given, can hardly be considered exaggerated by the most sceptical, though some are of opinion that Erasmus and others who wrote about the conditions of life in England saw the darkest side of things. Beyond all question the people of early England suffered very severely from famine and pestilence,

Leprosy, Ergotism or St. Anthony's fire, Scurvy, the Black Death, the Sweating Sickness, and Syphilis killed and mutilated their hundreds of thousands. To enable

sometimes separately and sometimes together, as happens at the present time in India; and not only so, but their domestic animals, the sheep, cows, pigs, etc., which, to the then rural population, meant food and money, were frequently destroyed in thousands by various plagues and 'murrains.' Creighton (*op. cit.*, p. 15) gives a list of the authenticated 'Famine-Pestilences' occurring in England between the years 679 and 1322, amounting to 42 in number and extending, sometimes, over several years. In England, and in other countries, the priesthood sought to show its power by forbidding the rite of burial, etc. "It was the papal method of checkmating the kingdoms of this world; that it was subversive of traditional decency and immemorial sanitary precaution was a small matter beside the assertion of the authority of Peter." The population, as mentioned before, was essentially rural and agricultural. "It would be within the mark to say that less than one-tenth of the population of England was urban in any distinctive sense of the term. After London, Norwich, York, and Lincoln, there were probably no towns with five thousand inhabitants." Any thing approaching the immense aggregations of human beings contained in the towns of Modern England, would have been impossible under those early conditions. "If there was 'rude plenty' in England, it was for a sparse population, and it was dependent upon the clemency of the skies. A bad season brought scarcity and murrain, and two bad seasons in succession brought famine and pestilence." Of one year, 1069, when the county of Yorkshire was 'harried', the historian, Simeon of Durham (quoted by Creighton), writes, "There was such hunger that men ate the flesh of their own kind, of horses, of dogs, and of cats. Others sold themselves into perpetual slavery in order that they might be able to sustain their miserable lives (like the Chinese in later times). Others setting out in exile from their country perished before their journey was ended. It was horrible to look into the houses and farm-yards, or by the wayside, and see the human corpses dissolved in corruption and crawling with worms. There was no one to bury them, for all were gone, either in flight or dead by the sword and famine. The country was one wide solitude and remained so for nine years." Of the famine in 1143, another writer (quoted by Creighton) observes, "There was the most dire famine in all England; the people ate the flesh of dogs and horses or the raw garbage of herbs and roots. * * * As autumn drew near and the fields whitened for the harvest, there was no one to reap them, for the cultivators were cut off by the pestilent hunger which had come between." In this case, as often in India, the harvest came too late to save the people; with this difference, however, that there was no thought of a million pounds sterling, or its then equivalent, being subscribed at a few days notice as a 'Famine Fund' for the starving. Then, as now, the wealthy few were apt to forget the starving many, though there were, and are, honourable exceptions. "In the year of great scarcity and mortality, 1322, there was such a crowd for a funeral dole at Blackfriars that fifty-five persons, children and adults, were crushed to death in the scramble. At the same time the prior of Christ Church, Canterbury, was sitting down to dinners of seventeen dishes, the cellarer had thirty-eight servants under him, the chamberlain and sacrist had large numbers of people employed as tailors, farriers, launderers and the like, and the servants and equipages of the one hundred and forty brethren were numerous and splendid." For detailed accounts of the Plague, Leprosy, Sweating Sickness, Small-pox, Influenza, etc., in the words of the various contemporaneous chroniclers, *v.* Creighton, *op. cit.*

the reader to grasp the appalling nature of these outbreaks the original descriptions must be read, but some idea of the mortality may be gathered from the fact that about two-thirds of the entire inhabitants of the known world are supposed to have perished, including about 25,000,000 in Europe alone.*

Towards the end of the middle ages (1300—1500 A. D.) the frequency and magnitude of these outbreaks compelled attention to two points, *viz.*, the necessity for isolation of the sick and the establishment of 'quarantine' † to prevent infection. Various attempts were made to keep the sick separate from the healthy, occasionally with success, but more often uselessly. So also, the attempts to prevent the introduction of disease by keeping ships arriving from foreign ports in quarantine for forty days, generally ended in failure. As will be seen later, to prevent or stamp out an epidemic in a place where the sanitary conditions are entirely defective, is almost invariably a hopeless attempt, and further, it is beginning the wrong way about. *Prevention* is the watchword of modern hygiene, and it is only by constantly keeping a place in a condition of scrupulous cleanliness that any effectual resistance can be offered to the attacks of epidemic disease. It is worthy of note, however, with reference to the gradual evolution of hygienic measures, that a 'Board of Supervision', which gradually became a model for all Italy, was established in Venice in 1348, a 'Sanitary Commission' in Paris in 1350, and similar attempts to cope with epidemics were made in other cities.

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* Towards which London is said to have contributed 100,000 human victims to the Black Death in 1349. These figures are probably much in excess of the reality, but it should be remembered that the population of London at that time was little more than 100,000. The whole subject is clearly and ably discussed by Creighton, *op. cit.*, who certainly does not err on the side of exaggeration.

† Derived from the Italian numeral *quaranta* meaning 40. The reason for the selection of a term of forty days is disputed, the selection being made on medical grounds according to some, owing to the teachings of Hippocrates, and on religious grounds according to others. Lepers were really the first diseased people isolated and placed in quarantine, and the name *lazaretto*, meaning 'leper-hospital', is still applied in Europe to quarantine establishments.

Coming now to the never-to-be-forgotten sixteenth century, we begin to leave behind us the superstitions and follies of the dark period preceding and can trace the beginning of that marvellous awakening in all directions of human thought and ingenuity, from which, with occasional and temporary relapses, has resulted the enormous improvement in the moral and social condition of the leading European nations and has spread or is spreading from thence to America, to Asia, to Africa, and the farthest portions of the world.

It was a veritable awakening from the sleep of death. "Not only the lofty, in a social and intellectual sense, often hazarded their all for the attainment of higher intellectual and moral objects, but the common people likewise took part with enthusiasm in the reformation. * * * The fundamental chord of the whole century was thoroughly idealistic and its result was an astonishing creative activity towards every point of the intellectual compass—in religion, the arts, the sciences, technics and social life. * * * The 16th century ripened free investigation, and in medicine too was peculiarly the century of reformation, of struggle and of protest against all medicine which had abandoned the * * * principles which placed the observation of nature, not the letter of tradition, in the forefront of knowledge." But all was not plain sailing. "Beside an earnest effort to advance, a retrograde impulse of almost equal strength exerted itself; beside the clearest discernment appeared the darkest superstition; beside poor dupes stood the grandest impostors; beside philanthropic efforts were deeds of the most terrible delusion; in short, we observe a collection of revelations and riddles of the human mind * * * such as no other period can offer." Yet many wise and excellent laws were enacted in Europe, relating, more especially, to the prevalent plagues, and which were known as the 'Pest-Ordinances'. They were wise in that they showed a power of observation and recognition of causes hitherto almost entirely latent, but failed to a large extent in their effect, like many modern

regulations, from a variety of reasons, *e.g.*, imperfect knowledge, want of thoroughness, and a general absence of personal hygiene. "With a view to disinfection, horn, gunpowder, arsenic with sulphur, or straw moistened with wine, etc., were burned in the streets, so that the statement "They are burning horn" signified at that time "The plague is there and we can do nothing against it", a condition which we now express euphemistically by the odour of carbolic acid. The administration of preventive doses of disinfectants was also customary at that period. The Pest Medici anointed the uncovered portions of their bodies with oil, etc., or wore special 'plague-dresses' and 'plague-masks', 'plague-gloves,' etc. The plague-dresses were red and black; the masks were made of leather, had openings fitted with glass for the eyes and a beak-like prolongation for the reception of disinfecting substances." Certain epidemic diseases such as the plague still raged with great violence, others such as leprosy and the sweating sickness almost entirely disappeared, whilst yet others such as spotted typhus (intermediate between the plague and typhus), small-pox, influenza and diphtheria put in their first historical European appearance. Influenza, indeed, became pandemic in Europe at least four times in this century, *viz.*, in 1510, 1557, 1580, and 1593, and smaller outbreaks occurred between. As in this country, the evils wrought by centuries of filth and the neglect of the simplest rules of hygiene could not be even partially controlled for many a long year.

In Germany, especially, the first earnest endeavours were made to grapple with preventable disease by the issue of ordinances of medical police relating to the sale of food, popular amusements, adulteration of wine, etc. In Frankfort-on-the-Main the medical ordinance of 1577 directed: "1. In order to improve the air the streets shall be cleaned Wednesday and Saturday of each week after the closing of the market; 2. The passing of urine in the streets is prohibited*; 3. Privies shall be erected in all houses;

* *cf.* Indian towns, in 1898, A.D.

4. The knacker shall transact business only during cold weather; 5. The shops of butchers, tanners, fishermen and farriers shall be removed. 6. Hog-pens, goose-pens and wells shall be cleaned," etc., etc. In England, too, interest in these and allied matters, *e.g.*, the more humane treatment of the insane, was aroused amongst the intelligent, but the progress made was "slow, tedious and tentative," and it was not till the great fire of London in 1666, following close on the plague,* swept away the whole town from Temple Bar to the Tower that the people as a whole began to be aroused. Thirty-two years previous to this, however, the Royal College of Physicians presented to the Council in London a "Report on all such annoyances as they conceive likely to increase the sickness in this populous city. 1. The increase of buildings by which multitudes are drawn hither to inhabit. 2. Inmates by whom houses are so pestered that they become unwholesome. 3. Neglect of cleansing the common sewers and town ditches, and permitting standing ponds† in inns. 4. The uncleanness of the streets. 5. Laystalls so near the city especially on the north side. 6. Slaughter-houses. 7. Burying of infected persons in churches and churchyards in the city. Overlaying the churches with burials, so that many times they take up bodies to make way for more burials. 8. Carrying up funnels to the tops of houses from privies and vaults. 9. Selling musty corn, and baking bread thereof, and brewers using unsound malt. 10. Butchers selling unsound cattle. 11. Tainted fish." In this most sensible and practical report the formation of a "Commission or Office of Health" was suggested but, as too frequently happens, no attempt seems to have been made by the Council to give effect to the suggestions offered.

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* The following table, from Creighton, *op. cit.*, will give an idea of the mortality in London during the so-called 'Great Plague,' though it was not much more severe than those of 1603 and 1625 had been for the London of their generation.

Year.	Estimated Population.	Total Deaths.	Plague Deaths.	Highest Mortality in a week.
1603	250,000	42,940	33,347	3,385
1625	320,000	63,001	41,313	5,205
1665	460,000	97,306	68,596	8,297

† Comparable to the filthy tanks which still abound in Indian cities.

Amongst the people of England, also, the general conditions of life were becoming more healthy. "The gradual improvements in agriculture, manufactures and commerce were adding steadily to the comforts of life. Food was becoming more plentiful and the diet less coarse. Vegetables, and more especially the potato, were becoming much more generally used; fresh meat was taking the place of salted meat, which had hitherto constituted such a large part of the English dietary; while tea and coffee were to some extent replacing the strong ale and ardent spirits which had formerly proved such a baneful source of disease. People, too, were beginning to recognise the value of cleanliness of person and home. The introduction of soap and soda made washing easier, and cotton and linen articles of clothing were gradually coming into more general use." In fact, a gradual emancipation from the 'thraldom of filth' had begun and the benefit resulting therefrom soon began to be apparent. That is to say it is easily apparent when looked at from this distance of time, but it must not be imagined that any great effect was produced in the direction of checking epidemic disease till very near the end of the 17th century. The plague, which, as we have seen, appeared in London for the last time in 1665, lost its predominance in Europe by the end of the century, but till then it ran through country after country, *e.g.*, Italy was attacked in the years 1630, 1656, 1669, 1683 and 1691. During one epidemic in that country more than quarter of a million people perished in four cities alone. In Milan, two unfortunate people, one a Health Commissioner, were accused of rubbing plague salve on the walls of the houses, and, after various other tortures, had their hands cut off, were broken on the wheel and finally burned. In Germany, where the mass of people were much more enlightened, energetic precautions to prevent the introduction and spread of the disease were frequently taken.* In Magdeburg, in 1680, a physician,

* As illustrating the fact that there were even then, in the seventeenth century, wise and thoughtful persons, who studied the public health and

surgeon, minister, nurses, 24 inspectors of the streets, 24 corpse-bearers, and 12 grave-diggers for the plague were appointed by the magistrates in anticipation of its appearance, a plague-hospital was erected, and the house in which the first case of plague occurred was burnt down. In addition to this disease, malaria, dysentery, typhus fever, influenza, diphtheria and scarlet fever (accurately described for the first time) and numerous other diseases still continued to prevail. Malarial disease, owing to the still-defective drainage of the country, was terribly prevalent and included amongst its victims James I and Oliver Cromwell. From 1661—65 it was the most fatal disease in England.

By the commencement of the 18th century several of the more important plague-scourges had disappeared from England and the neighbouring countries, never, let us hope, to return. But other diseases, almost, if not equally deadly, remained, *e.g.*, small-pox, typhus, malaria, dysentery, influenza, scurvy and many others, and these had still to be attacked. In the case of small-pox, the very ancient practice of 'inoculation' was first introduced to England and the Western Continent from the East during this century, and later on was followed by Jenner's immortal discovery of vaccination. Typhus fever, known at that time as 'jail-fever', was rife, and to the lessening of that disease and the general improvement of the conditions of life of prisoners, John Howard, the Quaker philanthropist, devoted his means, energies and, ultimately, his life. For nearly eighteen years this man travelled throughout all parts of Europe, living in great discomfort and in frequent danger of his life both from disease and from the numerous enemies which his reforms created for him. Within one year after

well-being, the following quotation from a German writer (Ludwig) will shew. "No one should without necessity remain in the dwellings of patients suffering from dysentery, especially in the place where the discharges are placed. The latter should be taken to remote places and covered with lime or ashes. The beds, linen and clothing used by such patients should all be carefully washed. Before the dwellings in which such patients have been living are again occupied, we should not neglect to fumigate and clean them thoroughly."

he had begun his work in England and given his preliminary evidence before the House of Commons, Bills were passed for the reform not only of jail-routine, but also directing the construction of suitable jails, with hospitals for sick prisoners attached to them, and that all the buildings should be properly cleaned and ventilated. Two or three years later he published his classical work *The State of Prisons,* and later on added two important appendices. In 1789 he started, in further prosecution of his researches on jail-fever, on what proved to be his last journey, for at Cherson, in Russian Tartary, he caught the 'bubo-plague' which was there prevalent and died. Of him, and the results of his work, one writer has said, "His influence did not die with him, for it has continued to influence not only the legislation of England but of all civilised nations down to the present time," whilst another has written, "The outcome of his self-sacrificing labours is simply this that for years back the prisons of this country have been proved by the most rigid statistics to be far healthier than our homes, and that so-called preventable disease of any kind is of such rare occurrence within their walls, that when any isolated cases do appear they at once give rise to surprise, and are sure to call for inquiry." All through the 18th century, wherever dirt and over-crowding prevailed, this dreaded disease, known variously as spotted fever, famine typhus, war-fever, putrid fever, etc., made its appearance. At Prague, in 1742, more than 30,000 of the French troops were carried off by it. Another disease, scurvy or scorbutus, which had frequently destroyed almost the entire crews of ships, so that the latter could not be navigated, and which constantly broke out amongst and decimated besiegers or besieged in continental wars, was successfully attacked and subdued by Captain Cook, that dauntless but humane sailor. He showed that its occurrence could be entirely prevented by the use of fresh vegetables or acid fruit juices, coupled with ordinary hygienic precautions. Within thirty years of the time when 600 men out of 900 died, mostly of scurvy, on Anson's

disastrous expedition, Captain Cook brought back 114 out of a total crew of 118 after three years continuous voyaging, and without a single death from scurvy.* Malaria and dysentery still prevailed, also, to a great extent in Europe during the last century, as well as Influenza or *La Grippe*, and Diphtheria, both of which latter diseases spread through almost the entire known world, including America.

In the early part of the century that terrible disease known as the 'bubo-plague', from the fact that the glands in the armpit and elsewhere were specially affected, the 'disease of barbarism' as it has been called, started from its then habitat the S. W. of Europe and, favoured in its spread by the Russo-Swedish war, travelled northwards and westwards, carrying off 300,000 persons in E. Prussia alone. Later on it again broke out several times, killing John Howard the prison-reformer as before mentioned, and causing terrible havoc in Russia. In that semi-civilised country a panic seized the inhabitants from highest to lowest, and Queen Catherine II. promptly beheaded the doctor who first correctly diagnosed the disease! This example was speedily followed by the densely ignorant people, and a regular insurrection, which necessitated the use of physical force to quell it, took place. In Moscow more than 52,000 people, or about one quarter of the entire population, died, the disease being increased by the number of concealed and putrefying corpses in the houses. It is a disease of particular interest to us in India, for it is

* With reference to the use of lime-juice as a preventive to scurvy, it should be noted that the valuable properties of the former in this direction had been known and made use of for a long time before Captain Cook's three years voyage, from 1772–75. At the end of the sixteenth and beginning of the seventeenth centuries, when the English trade with the East Indies was opened up, the commanders of the fleets, especially Hawkins and Lancaster, were in the habit of carrying lemons, etc., on board their ships. In addition, John Woodall, a well-known English surgeon of that date, who wrote a book called *The Surgeon's Mate*, "chiefly for the benefit of young sea surgions imployed in the East India Companie's affairs," alludes to the importance of giving lime-juice to the ship's company regularly, and advises various additional precautions regarding change of clothing, diet, sufficient exercise, etc. What Captain Cook did was to insist upon the necessity for precautions being invariably taken in this matter, and he also demonstrated, practically and convincingly, the great success of such preventive measures when properly carried out.

possibly identical with the plague which, under various names, has broken out at intervals in India, during the present century.*

General Hygiene received a large share of attention during the 18th century, and such subjects as dietetics or the systematic study of food-stuffs and beverages, the hygienic management of children, the influence of climate on health, etc., were freely written about. One notable German physician† even delivered simple lectures on hygiene to boys and girls over ten years of age. Military hygiene, hitherto merely conspicuous by its absence, was also studied to a certain extent, especially by British army surgeons, and the health and comfort of the unfortunate sick and wounded thereby increased and money saved to the State. About 1784 was published what was probably the most notable book on the subject of Public Health of that century, *viz.*, Frank's System of Medical Police, which has been considered by some to be the 'cornerstone of our modern public and private hygiene.' Amongst other things, the author of this book, a German physician, first pointedly drew the attention of those in authority to their duties as regards the health of their ignorant fellow men. Regular inquests on the dead were first established in this century, as also *morgues* (*i.e.*, special buildings where the unclaimed bodies of the dead were exposed to view), and institutions for the rescue and treatment of the apparently drowned, etc., etc. It is thus evident that hygiene in a general sense received a considerable share of attention during the last century, but the science of preventive medicine as applied to epidemic disease, owing doubtless to the general ignorance regarding the causation of these diseases, was still very imperfectly developed.

We have now brought our brief historical summary to a point at which we may profitably pause for a little while

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* *v. Trans. Med. Phys. Soc.*, of Bombay, and Chevers' *Diseases of India*, and references given therein. The 'Black Death' was a similar, if not identical, complaint, and both were eminently 'filth-diseases.'

† Fr. Ant. May, of Heidelberg: *v.* Baas, *op. cit.*, p. 715.

and take a backward glançe to see what lessons are derivable from the study of the gradual development of the art of hygiene—for it was still merely an art and not a science. Of the earliest nations of whom there is historical record not much more can be learnt than the fact that the rich and learned knew and appreciated the value of personal cleanliness, but at best it was an imperfect and eminently selfish knowledge. With the Jews came a strict code of priestly ordinances applicable to all, rich and poor alike, thoroughly suited to their mode of life and stage of civilisation, and by means of which they may with accuracy claim to have *prevented* to a considerable extent an otherwise certain and large mortality. So too the early Romans, self-disciplined and law-abiding, gave evidence, by their laws and enactments, their special officials, their baths, aqueducts and cloacæ, of their recognition of the extremely important position occupied by sanitation in any thorough scheme of government, and later, when scepticism and luxury held chief sway, found to their cost that an enemy infinitely more powerful and untiring than the Goths and Huns was clamouring for admittance, and that gates and walls alike were powerless to oppose or prevent its entrance.

Then came the long period of the Middle Ages when the old civilisation was giving place to the new, when war, famine, and pestilence stalked the land, when everyone was too busy cutting his neighbour's throat with one hand and protecting his own with the other to pay much attention to such matters as health and cleanliness. The monk in his cell, the courtier surrounded by every luxury, and, possibly, the inhabitants of isolated and thinly-populated districts, escaped to a certain extent, but the mass of the people, *i.e.*, those of them who escaped death in battle, were frequently attacked by infectious diseases of a most virulent type and rotted and died like sheep.

Still later, and chiefly in the sixteenth and seventeenth centuries, there were signs that men were at length

beginning to realise, though ever so faintly, that these horrors of disease and famine were—if not actually caused by—at all events increased by their own carelessness and filthy habits, and from this recognition resulted attempts to cope with the evils, earnest enough, perhaps, but predestined to failure, partly from ignorance and partly from want of the co-operation of others.

From the commencement of the eighteenth century the improvements in manners and the mode of living began to tell favourably, and certain diseases disappeared from England. Small-pox, Scurvy and Typhus Fever still held the field, however, but each in turn was attacked and routed by the stout-hearted philanthropists—Jenner, Cook and Howard—who achieved in their fights a measure of success unknown to any of their predecessors from the fact that they were enabled, by their brilliant discoveries, to *prevent* the occurrence of these diseases by rendering human beings proof against their power.

Coming now to the commencement of the present century we find ourselves confronted by such an immense degree of activity and progress in the direction of hygienic reform, that it is necessary to confine our attention to the general course of events in England, and even of this only the merest outline can be given. During the early years of the nineteenth century the thoughts of the people were principally concentrated on British battles by land and sea and on the increase of the country's possessions and commercial prosperity. Though the drain on the population from the continuous demand for recruits* and from disease was still excessive, the increased healthiness resulting from improved conditions of life had reduced the mean annual death-rate from 80 per 1,000 in the seventeenth century to 22 per 1,000; an enormous reduction,

* "War is without doubt the most hideous physical curse which fallen man inflicts upon himself; and for the simple reason that it reverses the very laws of nature, and is more cruel even than pestilence. For instead of issuing in the survival of the fittest [?], it issues in the survival of the less fit, and therefore, if protracted, must deteriorate generations yet unborn."—Chas. Kingsley.

representing a saving of 17,000 lives annually in a population of 300,000. So that in spite of all, the population of England was increasing.

From the discovery and application of steam power there resulted an enormous impetus to trade, and following this there took place a change in the habits and surroundings of the English people the full consequences of which cannot be determined even yet. This was nothing more nor less than the rapid centralisation in a few great towns of a population which had hitherto been characteristically rural and agricultural. A few figures may help to render the subject clearer. As stated above, the population of England, since the latter part of the eighteenth century had been steadily increasing, but this increase had taken place almost entirely in the country districts. Outside London there was no town of 100,000 inhabitants and only 5 with more than 50,000. There are now 7 towns with a population of over 250,000 inhabitants, 15 towns with about 100,000 inhabitants, and very numerous other towns with 50,000 inhabitants or more. All these are situated in England alone, excluding Scotland and Ireland, *i.e.*, in a country with a total area of about 50,000 square miles, or about $\frac{1}{3}$ of the size of the Madras Presidency. Just at the time, then, when it seemed as if the increase of population in England would continue unchecked and in increasing ratio, the whole condition of things was reversed or rather, tended to be reversed; for, as will be seen, in spite of this enormous centralisation of the population in towns in place of its former rural distribution, the numerical increase has been steadily maintained. In 1810, the population of England (including Wales) was about 10,000,000; in eighty years it has just trebled itself, so that now it is about 30,000,000. Great, then, and serious, as were the errors made by the early pioneers of hygiene in England, it may be confidently asserted that such an immense numerical increase in the population of a country in face of the countless evils and drawbacks inseparable

from rapid concentration in towns, would have been absolutely impossible under any conditions approximating to those that obtained throughout Europe up to the end of the fifteenth century or even later.

From the commencement of the nineteenth century to the battle of Waterloo (1815) was indeed a most important period in the social history of England. "English exports had nearly doubled since the opening of the century. Manufactures profited by the discoveries of Watt and Arkwright; and the consumption of raw cotton in the mills of Lancashire rose during the same period from fifty to a hundred millions of pounds. The vast accumulation of capital, as well as the vast increase of the population at this time, told upon the land, and forced agriculture into a feverish and unhealthy prosperity. Wheat rose to famine prices, and the value of land rose in proportion with the price of wheat. Inclosures went on with prodigious rapidity; the income of every landowner was doubled, while the farmers were able to introduce improvements into the processes of agriculture which changed the whole face of the country. But if the increase of wealth was enormous, its distribution was partial. During the fifteen years which preceded Waterloo, the number of the population rose from ten to thirteen millions, and this rapid increase kept down the rate of wages, which would naturally have advanced in a corresponding degree with the increase in the national wealth. Even manufactures, though destined in the long run to benefit the labouring classes, seemed at first rather to depress them; for one of the earliest results of the introduction of machinery was the ruin of a number of small trades which were carried on at home, and the pauperization of families who relied on them for support. In the winter of 1811 the terrible pressure of this transition from handicraft to machinery was seen in the Luddite, or machine-breaking, riots which broke out over the northern and midland counties; and which were only suppressed by military force. While

labour was thus thrown out of its older grooves, and the rate of wages kept down at an artificially low figure by the rapid increase of population, the rise in the price of wheat, which brought wealth to the landowner and the farmer, brought famine and death to the poor, for England was cut off by the war from the vast corn-fields of the Continent or of America, which now-a-days redress from their abundance the results of a bad harvest. Scarcity was followed by a terrible pauperization of the labouring classes. The amount of the poor-rate rose fifty per cent.; and with the increase of poverty followed its inevitable result, the increase of crime. The natural relation of trade and commerce to the general wealth of the people at large was thus disturbed by the peculiar circumstances of the time. The war enriched the landowner, the farmer, the merchant, the manufacturer; but it impoverished the poor."* It will be seen, then, that sanitary reformers had indeed a difficult task before them, with a population rapidly increasing and becoming more and more concentrated in towns made up of hastily-built and imperfect houses; with wealth unevenly distributed, and therefore difficult of just and sufficient taxation; and with the minds of men concentrated on wars abroad and class factions at home.

With reference to the rapid increase in population, the following able summary† of the then existing conditions, and their pernicious effects on future generations, may help the reader to realise the state of matters. "But under what conditions [had this increase in population taken place]? For the most part in the dust and din of factories; the vitiated air of mines; the stifling atmosphere of workshops; the bustle of busy warehouses; and, when the day's work was done, in overcrowded houses or underground cellars, heaped together in filthy, narrow, and unventilated streets or reeking back slums. Even in the construction of better class houses the veriest rudiments of sanitation were

* Green, *A Short History of the English People*, pp. 828—9.
† Wilson, *op. cit.*

neglected, because they were still but little understood and less appreciated. Instead of Municipal control there was general apathy. Sewers had to be constructed, but they were of the worst possible description, uneven, leaky, unventilated and incapable of being flushed, while the house drains leading into them were quite as faulty and imperfect. Scavenging was neglected, filth accumulated everywhere, cess-pits multiplied and wells became polluted. But why fill up the disgusting details of the picture? The mischief was done, and in spite of recent improvements and legislative enactments it will take years of steady, earnest, sanitary work and millions of money to undo it. The money no doubt will be forthcoming and the cleansing of the Augean stables may be accomplished in time, but the squalor, the misery, the disease, the physical deterioration, and the moral degradation engendered have imposed a load of vitiated heritage which will tell on generations yet unborn and which at the present day is crushing thousands of children into an early grave." For a number of years, then, instead of any real progress being made in practical sanitation, careful examination of the facts of the case shows that it was really the other way; for bad or defective sanitation is far worse than no sanitation, as hasty or careless legislation is worst than none at all, and only creates evils instead of mitigating them. Beyond the fact that the ruling bodies of some few towns asked for Parliamentary powers to enable them to provide drainage and water supply, nothing much was done.

In 1831 Cholera made its dreaded appearance for the first time on English soil and this fact coupled with the earnest and unceasing labours and writings of the rising generation of sanitary pioneers forcibly directed the attention of Government to the state of affairs. In 1832 a most important move was made, by the establishment of a Statistical Office in the Department of the Board of Trade, for the purpose of collecting, arranging and publishing statements relating to the conditions and various interests of the British Empire. In 1837 the Registration Act was passed,

and the first Annual Report of the Registrar-General, by the distinguished Dr. Farr, was issued in 1839; so that from the year 1838 onwards there is an unbroken series of statistical reports dealing with the pnblic health of England, which now forms a vast and increasingly valuable storehouse of facts bearing upon Hygiene. In 1833 a Factory Act* dealing with the ages of children and women working in the great factories, and kindred matters, was passed, and in the following year the Poor Law Amendment Act, but these were more or less of an imperfect and permissive nature.

Nothing further of any magnitude was attempted for ten years, but the gradually accumulating evidence in the returns of the Registrar-General, and the persistence of the sanitarians before mentioned, at length induced Parliament to appoint the celebrated Health of Towns Commission. To every town of any size in England a long list of queries was sent, having reference to the most important points in connection with the sanitary question, and from every large town there came back, with for little variation, the same "terrible series of replies—bad drainage, polluted water, unhealthy houses, overcrowding, filth everywhere; and, as a consequence, an excessive death-rate, with fever and filth-diseases of every description adding enormously to the death-roll. But so powerful were vested interests, and so strong the opposition to interference with the liberty of the subject or of corporate bodies, that it was not till the country was threatened with a second visitation of cholera as severe as the epidemic of 1831, that Parliament became alarmed and passed the Public Health Act of 1848. Under this Act, the General Board of Health was constituted, with a staff of inspectors who were empowered to hold pnblic inquiries and report on the sanitary condition of towns which according to the returns of the Registrar-General showed an excessive rate of mortality. From the passing of this Act, that is less

* Other Factory Acts was passed in 1844, '56, '71, and '74.

than fifty years ago, the sanitary legislation of England may be said to date, but this act unfortunately was, like too many later acts, of a permissive nature, and as a consequence, the beneficial results which might have been expected to accrue from it were long in appearing, and were by no means general. Nevertheless, it originated an era of active sanitary improvement in most of our large towns, and it merits special notice as the first outspoken recognition on the part of the legislature, that the health of the State concerns the statesman. By enabling town authorities to borrow money and spread the expense of public works over a number of years, it removed one of the greatest obstacles of sanitation, and as a consequence, extensive schemes of sewerage and water supply were soon undertaken in many parts of the country." But the art of sanitary engineering was unhappily still in its infancy, and the result was the construction of numerous and extensive systems of sewerage which only removed the sewage, and that imperfectly, from one town, to discharge it into the nearest river, where it speedily became a nuisance and a danger of the gravest order to the towns situated lower down on the river.

The first move having thus been made in the direction of sanitary legislation was speedily followed by further action, and during the next twenty-five years or so, *i.e.*, between 1849 and 1874, a large number of Acts were passed dealing with various branches of sanitary reform. Amongst these Acts, the names of which sufficiently indicate their purpose, were the Common Lodging Houses Act, 1851, the Labouring Classes Lodging Houses Act, 1852, the Metropolis Amendment Act, the Nuisances Removal Act, the Diseases Prevention Act, all of 1855. In 1858 the powers of the General Board of Health were transferred to the Privy Council, and in the same year the Local Government Board Act, which consolidated to a large degree the previous sanitary Acts, was passed. Mr., now Sir John, Simon, K.C.B., was appointed Medical Officer to the Privy Council, and had placed under his control a staff of able and efficient medical inspectors.

The work done by these men in the face of much doubt and opposition is simply invaluable. One experienced writer in alluding to this subject has said, "The material causes of disease were investigated with a minuteness and completeness of detail which could not fail to influence the most sceptical, and the series of reports in which these investigations are embodied and commented on have become the classics of sanitary literature. To any one who takes the trouble to read these reports*, it becomes at once apparent that whatever of purely beneficial sanitary legislation which has subsequently come into force has all along been largely indebted to Mr. Simon's foresight and advocacy, based on the inquiries of such able co-adjutors as, Seaton, Greenhow, Buchanan, Hunter, Thorne, Nelten-Radcliffe, Ballard and others." The reports deal with the nature and spread of typhoid fever and cholera; with the huge subject of injurious trades and occupations; with overcrowding in houses, adulteration of food, the sale of impure drugs, the adulteration of milk, impure water supply; with the leading part played by filth in the distribution of disease; with diseases of animals; with small-pox and vaccination; and with a host of other important questions. As a result of these labours, further measures, which it is unnecessary to describe in detail, were passed by Parliament, culminating, in 1875,† in the important Public Health Act which consolidated the previous Acts and led to the repeal of 19 of these and affected 16 others. Since then numerous Acts have been passed, the following being the more important; the Sale of Food and Drugs Act, 1875; Contagious Diseases (Animals) Act, and Rivers Pollution Act, 1876; Factory Acts, 1878 and 1883; Public Health Amendment Act, 1890; and, finally,

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* The study of these reports by all who pretend to a knowledge of hygiene is absolutely essential, and many of them form models for sanitary investigation which it would be hard to improve upon. They can be studied in their original form, or in the *Public Health Reports* by John Simon, Vol. II., published by the San. Institute.

† A few years previously, the divided powers of the Poor Law Board and Privy Council were vested in the Local Government Board, which latter henceforth became the Central and Governing Body in matters sanitary.

the very important Public Health (London) Act, 1891, the latest and most advanced in ideas, upon which the next Public Health Act for the country (England) in general must be more or less modelled. It is thus apparent that an enormous amount of thought and attention has been given to sanitary matters during the last fifty years, and it follows that, in England, hygiene has assumed a position of great importance, and that the duties of the health department are of the most varied and extensive nature. For many years English laws have formed the basis of sanitary legislation in other countries.*

At this point, and before considering the effect upon the general health of the community of the various sanitary reforms of the century, attention may be very shortly directed to the important changes made in regard to the hygiene of the army. In olden times it was the invariable rule that an invading army lost by far the greater number of its soldiers from disease and not from battle. The short Austro-Prussian campaign of 1866 is said to have been the first war in which the number of those killed in battle exceeded that of those killed by disease. In 1854 came the Crimean war, a war carried on with a base of operations maintained at the sea coast, between which and England there was at all times free communication. Yet, in spite of this, the amount of disease and misery, of easily-preventable disease and misery, endured by our troops was appalling. It was due chiefly to a faulty commissariat, *i.e.*, the issue and passing of bad or rotten stores by English army contractors and their supervisors, and also to an utter neglect of scavenging and cleanliness, coupled with an incredible disregard of the most rudimentary conditions of health. At a later period in the same campaign, when the English nation made one of those stupendous and unequalled efforts to redeem its past mistakes, the mortality was very greatly reduced

* *v.* Speeches of foreign delegates at VIIth Internat. San. Sci. Congress, Vol. I. of the *Transactions*. For further details regarding sanitary legislation, *v.* Vol. II., Part V. of this book.

and the healthiness of the troops in the Crimea compared favourably with that of the regiments quartered in England. In the China war, where great attention was paid to health, the mortality was just one-tenth of that in the Crimea during the early part of the latter campaign. As a result of official enquiry, and the heroic labours of Florence Nightingale, Edmund Parkes, and others, the Royal Commission on the Health of the Army was ordered in 1857. Following the most valuable work of this Commission came the Report of the Barracks and Hospitals Commission, and the Commission on the Health of the Army in India. "All these demonstrated," says one authority, "in the most complete manner that the sick-rate and death-rate of the army were culpably excessive; while the adoption of their recommendations, under the able teaching of the late lamented Dr. Parkes, afforded such conclusive proofs of the grand policy of prevention, that a stimulus to sanitary reform began to permeate the more intelligent classes among the general community which has continued to increase ever since."

The Royal Commission appointed to inquire into the Sanitary State of the Indian Army assembled on 31st May 1859, and directed that attention should be paid to the following points: 1. The rate of sickness and mortality; 2. The cause of such sickness and mortality; 3. The comparative healthiness of the different existing stations; 4. The subject of healthy positions generally; 5. The best construction of barracks, huts, hospitals and tents for India; 6. The present regulations for preserving the health of troops and enforcing medical and sanitary police; 7. The organisation of the army sanitary and medical service; 8. The practicability of establishing a general system of military statistics throughout India, and what changes it might be considered expedient to make in present practise on the above mentioned subjects. The voluminous report on this subject was forwarded to England in 1863 and considered at Home by the Royal Com-

mission sitting there; after which the latter made the following recommendations to the Government of India. 1. The appointment of a Sanitary Commission at each of the Presidencies. 2. A careful consideration of the changes that may be necessary in the present distribution of the European troops. 3. The selection of sites for new barracks and hospitals, the construction of those buildings on approved principles, and the application, as far as possible, of those principles to existing buildings. 4. The regulation of the diet of the European troops, and the prevention, if possible, of the use by them of ardent spirits. 5. The provision of means for the innocent recreation and healthy occupation of the men. 6. The measures to be adopted to prevent the spread of venereal disease. A lengthy dispute took place between the Home and Indian Governments, the latter feeling itself aggrieved, and with some show of justice,* that its previous labours for the health of the Indian Army had not been more fully recognised by the Home Commission. The Home Commission however stuck to its guns and proved ultimately that the principle cantonments of the English Army were on some of the unhealthiest sites in India, that the mortality of the European force in India had been on an average at the rate of 69 per thousand down to the year 1856 and was higher in the excluded mutiny years, that such waste of life was unnecessary and could be reduced by careful

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* "The announcement of the Commission that the death-rate of European soldiers in India averaged 69 per 1,000 annually, was received with astonishment and indignation. It was said in the House of Commons that this report had disclosed a state of things which no one had believed to exist. Yet that statement ought not to have been possible, because previous to the appearance of the Commission's report there had passed through the press such works as Colonel Sykes' *Statistical Tables*; Macpherson's *Statistics*; Ewart's *Vital Statistics of the Anglo-Indian Armies*; Chevers' *On the Means of Preserving the Health of the European Army in India*; and my [Moore's] *Health in the Tropics or the Sanitary Art applied to Europeans in India*; all reiterating the fact of Europeans *disappearing* at the rate of 69 per 1,000." Sir W. Moore, *San. Progress in India*, v. Trans. viith San. Sci. Congress. There is but little reason to believe that the House of Commons, as a body, is even now well-informed as to the work done by the pioneers of sanitation in India, and the imperative need for the encouragement of Hygiene in all its branches in that country.

attention to sanitation, etc., etc. In the report of the Indian Commission, the greatest pains were taken to secure accuracy : "Three series of questions were sent to 175 stations in the three Presidencies and the answers received in time from the commanding, engineering and medical officers of 117 stations are printed in an appendix to the evidence; with observations on the said returns by Miss Nightingale; with statistics of the East India Company's army, extending nearly from its origin, down to the latest date, by Dr. Farr; with statistics of Her Majesty's troops in India by Dr. Balfour; and statistics of regiments which had served in India by their commanding officers.

To give an idea of the amount of sickness amongst troops the following is quoted from official sources. "Some of the heaviest losses occurred in time of peace and to regiments when they were not in action. The following is an example :—All the Bengal regiments enter India at the stations about Calcutta, Fort William, Dum Dum, Barrackpore, and Chinsura. The 29th Regiment of foot arrived 1,004 strong in India, on 29th July, 1842; at Chinsura it lost 106 men in eight months; at Ghazipore and Meerut 418 men in the two next years, before it had seen an enemy: its valour was not extinguished, for 141 of the men were killed or died of their wounds in the Sutlej campaign and 48 in the Punjab. It lost 1661 men in all by death in India, and sent home 461 invalids, etc., before it embarked with a strength of 824 for England on 30th September 1859." But the authorities* in India had in reality been far from idle for years before the Royal Commission was appointed, and the interesting fact comes out clearly that the reduction in the mortality which was hoped for by the Commission, namely from 69 per thousand to 20 per thousand, was almost attained by the time that the Indian

* *i.e.*, The leading medical officers, backed by some few of the more enlightened commanding officers, such as Hodgson and Peel. As a rule, however, but little attention was paid to their warnings, their reports being conveniently pigeon-holed—a practice by no means extinct in official circles yet; *v.*, also, Trans. VIIth San. Sci. Cong., Vol. XI., p. 21.

Commission was assembled. "The hope of the Sanitary Commission," says the report, "that by improved sanitary arrangements the death-rate may be reduced to 20 per thousand, and thus only 1,460 recruits be needed annually to replace death vacancies in India, was practically realised before the publication of their Report."

A later Sanitary Despatch, dated 23rd April 1868, dealing with the whole question of the future sanitation of India, concluded thus: "Practically it would be impossible to introduce into India a complete cut and dried system of sanitary administration. Our ultimate success depends on carefully obtained experience. We know everything that requires to be done but we do not know the best way of doing it over so great a continent: we shall arrive at this only by experience, but the result will be the civilization of India. These remarks of course apply to the civil question only. There is no difficulty whatever in completing at once the organization for ensuring the health of troops, if only it can be provided at the same time that the measures recommended by commanding officers under advice of their medical sanitary officers, are promptly and efficiently carried out." And, as a matter of fact, the measures recommended by commanding officers, under advice of military medical officers, have been, since that time, efficiently and promptly carried out to a considerable extent, for the former have been led to realise by practical experience that upon the healthiness of a regiment depends very largely its discipline and effectiveness, whether in peace or war.

The Victorian Era has rightly been called the "Age of Sanitation."* Up to the commencement of the present century the subject of sanitation can hardly be said to have attracted attention except amongst a few military surgeons and thoughtful civilians. The books dealing with it were few and imperfect, whereas now there is such a vast and

* "The Victorian Era is the age of sanitary and social reforms—of diminished sickness, of increased longevity." Sir Chas. Cameron.

ever-increasing array of reports, blue-books, magazines and text-books, dealing solely with hygiene, that it is extremely difficult for any one to keep themselves fully informed of the latest discoveries or methods. Then again, as before stated, the early sanitary acts were largely of a permissive nature, and therefore almost inoperative, whilst the later ones have been, as far as possible, compulsory, and have accordingly exercised a most beneficial influence upon the public health and well-being. Thirdly, at the commencement of this century the public health was nobody's concern in particular. Now every town of any size, and every rural district, has its own Medical Officer of Health and a large number of other officials concerned with sanitation; whilst the central and governing organisation—the Local Government Board—has a most complete and efficient staff of Medical Inspectors and others for routine and expert duties. One thing is still wanting and that is a direct representative of the health of Great Britain in the person of a Minister of Health, with a seat in the Cabinet, but it is only a matter of time till such an appointment is made. So also, at all universities and other centres of medical training the teaching of hygiene has of late years received great attention; though in one respect, the means for research into the causes and methods of prevention of diseases, Great Britain is far behind her European neighbours. In addition, the youth of both sexes are being trained whilst at school to a simple understanding of the construction of their bodies and of the laws which govern the preservation of health. It is, of course, too soon to try and estimate the great and lasting benefits that have followed, and are still following, from this immense expenditure of time, labour and money, but there are one or two points to which the student's attention may be shortly directed ere taking up the discussion of the full meaning and tendency of modern hygiene and its future influence on India.

In 1850, the medical officer of the General Board of Health laid before the President of that Board a most

careful and elaborately exact paper by Dr. Greenhow, on the Distribution of Disease in England. In this paper it was shown that the diseases chiefly causing the annual mortality were as follows :—(1.) Bowel complaints, including cholera (a disease new to England), dysentery and diarrhœa, (2.) Fevers, including especially typhus and typhoid or enteric, (3.) Pulmonary or lung affections, especially those included under the generic term of 'phthisis', and (4.) In the case of children, measles, whooping cough, scarlatina and small-pox. An examination of this list will show how changed the types of fatal disease had become from those that characterised the earlier centuries. Small-pox was still prevalent it is true, but to a much less degree, and chiefly amongst unvaccinated children. Cholera had appeared, apparently for the first time, in Europe, spreading from India.* Typhoid or enteric fever, our present dreaded foe in India, if not occurring for the first time, was only distinguished from typhus in the year 1846†. Commenting on the immense loss of life due to almost entirely preventable causes, Sir John Simon says, "Looking at the last eight or nine years for which materials are before me," 1848—'55 or '56, "I find that the annual average of deaths by the three diarrhœal diseases has amounted to 26,388; by fevers (typhus, typhoid, infantile and remittent) to 18,616; by small-pox to 4,587; by tubercular diseases to 57,982; by non-tubercular respiratory diseases to 50,273; by the common infectious disorders to more than 32,000; by the nervous disorders of childhood, to nearly 37,000. Here altogether are 227,000 deaths annually distributed with utmost inequality. After reasonably estimating the degrees in which they severally are preventable, it can no longer

* This is denied by some, *e.g.*, Sir William Moore, but the point is immaterial to our present purpose. *v*, however, *post.*, Vol. II., Part III.

† The following interesting note on this matter occurs in Baas, *op. cit.*, p. 728. "The first description of typhoid fever—under the designation of 'Schleimfieber' (mucous fever)—appeared in the 18th century, and was due substantially to Roederer * * * and his pupil Karl Wagler. * * * As regards its etiology, these two observers already mention the contamination of the springs with filthy water. The disease was subsequently described by Sarcone in Naples, Armstrong, Campbell, Grant and Stoll."

seem so difficult to make a very large beginning towards striking off the annual 100,000 deaths against which the Registrar-General protests as deaths of artificial production." To give weight to this statement, there are here appended two tables from Dr. Greenhow's Report, illustrating how enormously the death-rate for the same diseases varies at different times and in different localities; and which go to prove that, to a large extent, the excessive mortality in certain districts is distinctly preventable.

I.—Annual death-rates from diseases which are either wholly, or almost wholly, preventable under good sanitary arrangements.

Cholera.	Diarrhœa and dysentery.	Continued fevers.	Small-pox.
From 0 to 403	From 4 to 345	From 21 to 209	From 0 to 146

II.—Annual death-rates from diseases which, to some extent, are inevitable, but of which the severity or frequency may be controlled by good sanitary arrangements.

Tubercular phthisis in women.	Non-tubercular lung diseases in men.	Common infectious disorders of childhood.	Convulsive disorders of childhood.
From 229 to 588	From 66 to 869	From 694 to 2,194	From 280 to 3,832

Twenty years later, Sir John Simon, in considering the same subject, and after an enormous amount of additional careful investigation in this direction had been carried on,

wrote as follows in the Thirteenth Report to the Privy Council. "It seems certain that the deaths which occur in this country are fully a third more numerous than they would be if our existing knowledge of the chief causes of disease were reasonably well applied throughout the country; that of deaths which in this sense may be called preventable, the average yearly number is now about 120,000; and that of the 120,000 cases of preventable suffering which thus in every year attain their final place in the death-register, each unit represents a larger or smaller group of other cases in which preventable disease, not ending in death, though often of far-reaching ill effects on life, has been suffered. And while these vast quantities of needless animal suffering, if regarded merely as such, would be matter for indignant human protest, it further has to be remembered as of legislative concern, that the physical strength of a people is an essential and main factor of national prosperity; that disease, so far as it affects the workers of the population, is in direct antagonism to industry; and that disease which affects the growing and reproductive part of a population must also be regarded as tending to the deterioration of the human race. . . There are also some indirect relations of this subject which seem to me scarcely less important than the direct. For, where that grievous excess of physical suffering is bred, large parts of the same soil yield, side by side with it, equal evils of another kind; and you will often have seen illustrated in my reports, that in some of the largest regions of insanitary influence, civilisation and morals suffer almost equally with health. At the present time, when popular education (which indeed in itself would be some security for better physical conditions of human life) has its importance fully recognised by the legislature, it may be opportune to remember that throughout the large area to which these observations apply, education is little likely to penetrate unless with amended sanitary law, nor human life to be morally raised, while physically it is so degraded and

squandered." These are weighty words indeed, and carry with them a grave responsibility on the part of all legislators and statesmen.

It is certainly extremely difficult to estimate the actual amount of good resulting up to the present time from all that has been done in the name of sanitary reform in England. As has before been pointed out, the peculiar and quite exceptional growth of population which has taken place during this century, and the immigration of that population into enormous towns, have not only increased the complexity of the problem of successful hygiene but, owing to general carelessness and crude and hasty efforts, have actually exercised a strong retarding influence, so that it has been said that the sanitation of the latter half of this century has consisted chiefly in the undoing of the mistakes made in earlier portions. With regard to the actual reduction in the death-rate since the early part of this century, it must be carefully remembered under what adverse conditions of poverty and over-crowding the mass of the people were forced to live.* The statistics for the years prior to 1838 are somewhat doubtful and even those from 1838 up to 1854 are probably defective. Still, it must be confessed that the death-rate which was undoubtedly greatly reduced towards the end of the eighteenth century, remained almost stationary through the period of over-crowding, poverty, and crude and hasty attempts at sanitation. Under those conditions, however, a stationary death-rate must be considered decidedly favourable, and it is certain that had these great and radical alterations in the distribution and habits of the English people taken place a century or two earlier the result would have an appalling outbreak of epidemic disease and probably of dire famine as well.† Instead of that, however, the population has steadily increased. From the passing of the Public Health Act in 1872 and the appointment of Medical Officers of Health, a steady

* *v. ante*, p. lxiv. † *v. footnote*, p. L.

decrease in the death-rate has taken place. The following extract may help to make this clearer.* "There is nothing in the series of annual reports issued by this office that comes out more distinctly and unmistakably than the wonderful effect which the sanitary operations of the last decade have had in saving life. The Public Health Act came into operation in 1872. The average annual death-rate for the immediately preceding ten years (1862—71) had been 22·6, and there were no indications whatsoever of any tendency of the rate to fall lower. Indeed in 1871, the final year of this period, the rate was exactly the average, *viz.*, 22·6. The Act came into force, and at once the rate began to fall, and continued to fall year by year with almost unbroken regularity, until in 1881 it was no more than 18·9. Once only in the ten years that had elapsed since the Act came into operation was the rate as high as the average of the previous decade. That was in 1875, when the rate was 22·7. In that year a second Public Health Act, of more stringent character, came into operation; and from that date down to 1881 the death-rate did not once reach 22·0, and averaged no more than 20·5.

"Had the fall in the death-rate been limited to a single year, or to two years, or even to three, it might have been argued by sceptical persons that the improvement was due to a succession of seasons favourable to health, or to other causes unconnected with sanitary administration, and that the setting in of the fall coincidently with the coming into operation of public health measures was no more than casual; but in face of a fall lasting for ten years in succession and increasing each year in amount, no one can seriously maintain such a position. There can be no real doubt that the saving effected in life was the direct product of the money and labour expended in sanitary improvements. Doubtless the money thus expended

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* *v. Annual Report* of the Registrar-General for the year 1881. The whole subject is fully discussed by Dr. Newsholme in his *Elements of Vital Statistics*, 3rd ed., 1892, (*q.v.*). *v.* also Vol. II., Part V., of this work.

was enormous in amount; and it will be well, therefore, to consider what return it has brought in. If, then, the death-rate in 1881 had been only equal to the average death-rate in the decade preceding the Public Health Act of 1872, there would have died in the course of that one year 96,917 persons who, as it was, survived. From this total, however, a deduction must be made of some 5,000 for the following reason :—The birth-rate in 1881 and in each of the two immediately preceding years was considerably below the average annual birth-rate in 1862—71. Consequently, there was a smaller than average proportion of children in the first three years of life in the population of 1881. But the death-rate at this early period of life is always very high. Had the birth-rate in 1879, 1880, 1881 been equal to the average birth-rate in 1862—71, there would have been so many more young children living in 1881 as to have increased the deaths in that year by a number close upon 5,000. Instead, therefore, of 96,917 lives saved, we have only about 92,000.

"Now we shall probably be well within the mark if we assume that for every fatal case of illness there are from four to five more cases which end in recovery. This is about the proportion in enteric fever, which is a more fatal disease than the average of diseases. The result, therefore, on this assumption, would be that, speaking in round numbers, there were 500,000 fewer cases of illness, and 92,000 fewer deaths in England and Wales in 1881 than would have been the case had the population been living under the conditions that existed in 1862—71. It may perhaps, be objected, and not unreasonably, that the year 1881, with its extraordinarily low death-rate, was so exceptional that it can hardly be taken as a fair sample by which to measure the annual return in life and health from the money spent in sanitary improvements. Let us then take the entire period of ten years that elapsed between the first Public Health Act and the close of 1881. Had the death-rate remained during that period at its

mean level in the preceding decade, the total deaths from 1872 to 1881 inclusively would have been 5,548,116; whereas they were actually no more than 5,155,367. Thus no less than 392,749 persons who, under the old *régime*, would have died, were, as a matter of fact, still living at the close of 1881. (The mean birth-rates in the two decades 1862—71 and 1872—81 were almost exactly the same, so that no correction need be made in this case). Add to these saved lives the avoidance of at least four times as many attacks of non-fatal illness, and we have the total profits as yet received from our sanitary expenditure. Moreover, it is important to note that these profits were not equally spread over the ten years, but that there was a manifest tendency to progressive increase throughout the period. This is what might be anticipated; for the full effect of sanitary improvements requires time for development."*

Beyond all doubt, then, and in spite of many errors, enormous progress has been made, progress which has raised England, with its present population of nearly 500 per square mile as against 149 per square mile in 1801, to the very forefront of nations in the scale of health.

Having thus completed a brief historical review of the development of the subject, from early times to the present century, it is necessary to consider what is now meant by

* If the death-rates between 1881 and 1888 are included, the improvement realized becomes even more striking (Newsholme). Thus—

	Period of Years.	Mean Annual Death-Rate per 1,000 Living.
	Ten Years, 1862—71	22·6
Public Health Act, 1872—	Four Years, 1872—75	21·8
Public Health Act, 1875—	Five Years, 1876—80	20·79
	Five Years, 1881—85	19·30
	1886	19·28
	1887	18·79
	1888	17·83

Hygiene and in what directions it is tending in its future expansion. There are, of course, various aspects under which the subject presents itself according to the point of view of the observer. For our present purpose it may conveniently be divided into (1) the Principles of Hygiene, the Science of Hygiene proper, and (2) the Practice of Hygiene, or the Art of Sanitation. In the former we are left far behind by the other great European nations with whom the systematic study of disease causation and prevention is made a national concern, and every encouragement and facility given to the workers in that wide field. But though this is the case, the fact remains that the British race is eminently quick and ready to measure the value of fresh discoveries and to adapt the newly-acquired knowledge to practical requirements, and thus the student of hygiene in England has generally access to the best and latest additions to sanitary measures and improvements.

Whether, however, one considers hygiene in its most comprehensive or in its most limited sense, it is evident that the central idea is always the improvement of the health and well-being of mankind. At first, as before remarked, it was a purely selfish art and related merely to the individual health of each human being, and that only of the wealthier classes. Later, men began to realise that attention to personal cleanliness, though excellent in its way, was in itself no guarantee of health if all around them were sunk in filth and disease. Still later came the idea that the State should take this matter of the public health to a certain extent under its own control, and by issuing laws and ordinances and appointing officials to see after the carrying out of the same, ensure a reasonable amount of protection to its subjects. From these three aspects, then, the subject of hygiene may be most conveniently studied, *viz.* :—

1. Man ...... in Relation to Self.
2. „ ...... „ „ „ His Surroundings.
3. „ ...... „ „ „ His Fellow Men.

In this work Part I., General Hygiene, is devoted to the consideration of man in relation to his surroundings; Part II., Individual Hygiene, to man in relation to self; and Parts IV. and V., Practical Sanitation and Sanitary Administration, to man in his relations to others, whether in his private capacity as a citizen, or as a unit of the Indian Empire, subject to the same privileges and penalties as his fellow-man. In Part III., the Ætiology and Prevention of Disease, special prominence is given to the scientific aspect of the subject, but as a matter of fact there is no hard and fast line of demarcation between the principles and practice of hygiene, and where an attempt is made to rigidly separate them, as used to be done in England and is still done in India, delay in the acquirement of valuable knowledge is certain to ensue on the one hand, and crude and imperfect attempts at sanitation to be made on the other hand. Now, it has over and over again been demonstrated clearly, for all to take the trouble to read, that "nothing is so costly in all ways as disease, and that nothing is so remunerative as the outlay which augments health, and in doing so augments the amount and value of the work done." Two things are therefore necessary if hygiene is to be the blessing it ought to be to the people of India, and an ultimately remunerative undertaking for the State. These are—Firstly, a continuous and patient investigation at several selected centres into the countless unsolved problems with regard to disease causation and prevention, from the detection and isolation of the actual *materies morbi* up to the most suitable and economical sanitary methods and appliances; Secondly, the absolute forbidding of any large sanitary measures or works being attempted unless previous experiment, public criticism or both, have demonstrated the probability of success, with the additional condition that the work itself shall be superintended from beginning to end by men who have solid claims to be considered experts in this particular subject. Disregard of these important points has cost England enormous sums of money and has retarded

the sanitary progress of that country by half a century, and India can but ill afford to neglect the dearly-bought experience of the richer and healthier country in this matter.*

Of man in relation of Self, as a sentient and rational being, but little need be said here save to note the extreme importance of impressing upon every member of the human race, while still young, the respect of his own body in all matters relating to health and the regulation of the desires. For such education youth is the proper time, before evil habits have corrupted the mind and weakened the body.

Next, as regards man in relation to his Surroundings, there are many things included under the latter term, such as the Air he breathes, the Water he drinks, the Food† he eats, the Clothing† he wears, the Dwelling he inhabits, the Soil he dwells upon, the Climate he lives in, the Disposal of the Waste Matter he gives rise to, etc., and it is the aim of the hygienist to ensure that men shall have pure air, water, food and soil, suitable clothing, dwellings and climate (as far as possible), and that all waste matter shall be speedily removed or rendered inoccuous. "But," say the ignorant, "why talk about pure air, pure water, suitable clothing and so on? Is not all water pure, is not the air the same everywhere, is not one sort of clothing as good as another, what is the harm of a little waste matter, as you call it"? To which questions the answer must be "No! all water is not pure—far from it—neither is air necessarily pure, nor all clothing suitable, and the waste matter that you would allow to accumulate around your dwelling is the worst of all, for it renders the air, the water and the soil impure, and I will prove what I say by showing you how diseases arise and spread, and how they may be prevented."

* If a man is to be called 'Sanitary Engineer' or 'Sanitary Officer', he should be one in deed and in fact. The idea that any engineer will make a competent Sanitary Engineer, and any medical officer a trained and earnest Sanitary Officer, let alone a specialist in hygiene, is still far too prevalent, and is a most costly and far-reaching error. *v.* also, Trans. viith Internat. San. Sci. Cong., Vol. XI., p. 160, *f. note*.

† Conveniently considered under Individual Hygiene, as they vary so much according to custom, climate, nationality, religion, etc.

Scurvy used to be a most deadly disease. Its cause was not known and therefore it could not be prevented. Now we know that it is due to hardship, exposure, etc., in conjunction with a defective dietary. It can therefore be prevented, and this prevention is brought about, chiefly by the provision of suitable food. Again, guinea-worm was, and is, still prevalent in many parts of this country. For a long time no one knew how or where the miniature form of the parasite gained admission to the human body. Now it is known to do so by means of impure water that is drunk. It can, therefore, be prevented by the use of pure water. Yet again, workers in match factories formerly suffered terribly from disease of the jaw bones. This was found to be due to the action of the phosphorus used in making the matches, upon teeth which had begun to decay. It can, therefore, be prevented by taking care that the air is not rendered impure by the fumes of the phosphorus, and this is done by using another form, the so-called red or amorphous phosphorus, which does not give off any injurious products.

Granted then that a man is cleanly and temperate, that his food, clothing, etc., are sufficient and suitable, that he takes trouble to ensure the purity of the water he drinks and of the air he breathes in his own house; is he properly safe-guarded at all points? By no means, and for this reason, that he may find it impossible to prevent his exposure to the risk of accident or disease from the ignorance, carelessness or greed of others. But what remedy is it possible to apply and who is to apply it, for it is evident that one man by himself would be quite unable to avoid or remove all sources of danger? In a rudimentary stage of civilisation, a man's health, and even his life, is no one's concern but his own; under more settled conditions he is protected from bodily violence; whilst only amongst the really civilised nations is it held to be the duty of the State to step in between its subjects and those who intentionally or even unintentionally might injure their

health. Of instances where such interference is necessary there are many which will occur to any thoughtful person. The danger of phosphorus poisoning have already been alluded to. Here it was found necessary for the authorities to intervene between employer and the employed, and order that the amorphous form of phosphorus should always be used in match making. And so with very many injurious trades, special laws, regulating the age, hours of work, means of protection, etc., of the workers, have been passed, one of the most noteworthy being the Employers' Liability Act of England, by which a workman killed or injured through defective provision for his safety, or his heirs, can obtain pecuniary compensation for the injury from the employer, if it be shown that the former did not contribute to the accident by his own negligence. It must not be imagined, however, that the persons for whose benefit the State has framed the laws are always ready to appreciate them or even to conform to the conditions imposed; on the contrary, through ignorance or a false idea of the liberty of the subject, they will frequently go out of their way to nullify the protection offered them. Therefore it is that early education in the elementary laws of physiology and hygiene is of such extreme importance, as enabling those taught to understand and value the restrictions placed upon the cupidity of employers or upon the licence of the ignorant or depraved.

Out of these three important relationships of man,—to self, to his surroundings, and to his fellowmen—has slowly and by degrees grown the modern science of Hygiene. Of its supreme importance there is no question, and the statesman or economist who fails to recognise this has no just claim to be considered either far-sighted or enlightened. Prominent as is the position now occupied by this question of the Public Health in all civilised countries, it may be safely prophesied that it will year by year receive still greater advancement, till by general consent it is acknowledged—*Salus Populi Suprema Lex.*

It remains, however, to examine a little closely into the causes of the obstruction, active or passive, with which sanitary reformers of all nations have been opposed. Such obstruction will be found to be due to one of the following, *viz.*, Simple Ignorance, Religious Superstition, Indolence (Bodily apathy), Fatalism (Spiritual apathy), Pecuniary Considerations, or Scientific Objections (so-called).

Under the heading of Simple Ignorance come two great classes of opponents to the progress of hygiene. In both defective education is at the root of the matter, but with the one class, which includes the majority of the unlearned, the opposition is the result of sincere ignorance of all matters in general save those relating to the bare necessities of daily existence. For these the greatest patience and consideration must be shown, the reasons for any sanitary measure explained in clear and easily-understood terms and, above all, they must not be frightened or coerced, save only, perhaps, when the matter is extremely urgent and of national importance. The second and smaller, but infinitely more harmful, class is composed of persons* who have received an education complete in many directions, but seriously defective in one important point—the training of the mind to the accurate and logical methods of thought which alone, save in rare instances, result from a scientific education. Amongst this class must be included many eminent persons in nearly every profession and occupation who have never, unfortunately, accustomed themselves to see how small a place they occupy in the scheme of the universe, nor have been shewn how infinitely valueless are their so-called 'opinions', compared with the lessons daily spread before them by the workings of nature, but which are hidden from their limited and partial mental vision. They receive mention here simply because of the fact that owing partly to their social position or distinction in a particular profession, and partly to the persistency with which they advocate their own peculiar craze or superstition,

* Most numerous in Great Britain, but not unknown in India.

they are able to command an amount of public attention entirely incommensurate with their real importance, and may thereby delay or hinder valuable and much-needed reforms. With such persons arguments and demonstrations are alike fruitless, and the only consolation derivable is the remembrance of the fact that the gradual spread of scientific knowledge amongst all classes is steadily lessening their numbers, and may even at some future date lead to their complete extermination.

To the opposition resulting from Religious Belief, or Superstition, allusion has already been made, and it has been shewn why it is that the priesthood of so many nations is jealous of a science which declares that disease is most frequently the natural consequence of man's imprudence or laziness, and is only rightly called a 'divine visitation' in that limited sense. Of particular religious customs it is unnecessary to speak here, save to emphasise the fact that many are essentially insanitary. At any place possessing a reputation of being particularly sacred and where, accordingly, enormous crowds of devotees assemble periodically, it is the primary duty of those who receive the revenues therefrom accruing to devote a sufficient portion of the latter for the efficient sanitation of the spot, and that not by feeble and spasmodic attempts after the appearance of disease, but by careful and thorough preparation for all emergencies beforehand. If, after proper warning, no attention is paid to this matter locally, it is the bounden duty of the authorities, with a view to the welfare of the population generally, to prohibit the holding of the religious festival or ceremony till their orders have been complied with. In this respect considerable improvement has taken place of late years in this country, but a great deal remains to be done.*

* At the present time the want of sanitary precautions and supervision in connection with the annual *Hadj* to Mecca is a disgrace to all concerned, and it is to be hoped that enlightened Muhammadans will insist on a complete reform in this matter and thus remove an evil which directly causes the death of many thousands of pilgrims, and is a standing menace to the health of the nations. It is reported that the Sultan has

Of passive obstruction, the result of Indolence or Fatalism, it must be confessed that whilst in all countries it is an important bar to sanitary progress it is pre-eminently so in the East. To a certain extent the existence of caste distinctions must be held responsible, for under this social code, so rigidly enforced for many generations, the lower orders are not encouraged to rise nor to improve their surroundings, and occupy therefore, a position in many respects similar to the serf in early England. There is no doubt that it is difficult for any one trained in the light and learning of western science, and accustomed to the general education and independence of the masses in Britain, to understand the mental attitude of the ordinary uneducated native of India who looks upon all disease as he looks upon the rainfall—"It may or may not come; if it is going to come it will come, if not it will not come: it is all a matter of fate and a man cannot alter that!" Years' of experience have taught him to take some little trouble in husbanding the supply of water, else how will he get food? But not so as regards the simplest provisions for warding off disease. And indeed the bodily circumstances of many millions in India are so straitened, and their surroundings so unhealthy through malaria and other diseases, that they may be said to continually dwell on the borderland between life and death, and thus a feeling of callousness, fatal to all self-respect and self-endeavour, is produced. Sanitation amongst the millions of India scattered throughout the land in small villages must for years be confined to the simplest measures; but from these simple measures, if carried out from a love of humanity and with the persistence characteristic of the true sanitary pioneer, there will assuredly result a great decrease in the mortality from preventable disease and, what is more important, an immense improvement in the stamina and well-

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ordered the construction of an immense lodging house capable of accommodating some 6,000 people, and if so, the latter is likely to afford an admirable centre of development for an epidemic. *v.*, also, discussion and tables, Trans. VIIth San. Sci. Cong., Vol. XI., p. 39, and B.M.J., 4th Nov. 1893, p. 1013, and references therein given.

being of the people. The question of village sanitation has received a considerable amount of attention lately from eminent civilians, medical officers and others, as also at the late International Congress on Sanitary Science (1891); and though it is undeniably difficult of solution, chiefly because of the apathy of the people themselves, and because of the immensity of the problem as compared with the ways and means available, it will certainly press itself more and more upon the attention of those in authority, till some one is found able and willing to devote the time, experience, and ability—possibly genius—that it demands for its proper settlement.

A frequent cause of delay in the progress of hygiene, and a powerful weapon in the hands of its opponents, when used with skill, is the question of the Pecuniary Considerations involved. On rare occasions, indeed, the cry thus raised may ultimately prove to be a blessing in disguise inasmuch as a scheme containing in itself the germs of good, but crudely and expensively planned, may, perforce, be delayed for revision and improvement; in addition to which, the money thus saved can be profitably applied elsewhere. This, however, is an unusual state of matters, and it is much commoner to find that an important reform or work is hindered and obstructed in every possible manner under the guise of 'undue expense,' until finally, when the condition of things is almost hopelessly bad, a most elaborate and costly remedy is sanctioned, the expense and benefits of which are in inverse ratio to what they would have been had permission been at once accorded to the original proposal. In some cases the cry of 'expense' is raised from perfectly sincere and honorable motives, and is simply the result of the official concerned not having fully grasped the fact that in a settled country, where there is no immediate danger to life from actual violence, *the public health is—not of great, but—of supreme importance, and should always take precedence in the estimates of expenditure.* As said before, no one who has not grasped this fact fully and clearly can claim to take front

rank as an administrator. And not only so, but he must give practical evidence that he has convinced himself of the absolute truth and accuracy of the already-quoted classic statement of Edmund Parkes—the result of years of careful work, observation, and unrivalled experience—that "*It has been proved over and over again that nothing is so costly in all ways as disease, and that nothing is so remunerative as the outlay which augments health, and in doing so augments the amount and value of the work done.*" Would that these two sentences, embodying both the financial and the moral or humane aspect of the question, were written in letters of gold in every Council chamber, Municipal office and Board room throughout India. It is not that there have not been, and are not, men who fully comprehend the unvarying truth and application of these principles, for there have been, and are, many such who have proclaimed these truths in season and out of season; but too often, alas, they have been as voices crying unheeded in the market-place or have been regarded as worthy but quite unpractical enthusiasts. Let any intelligent and well educated man consider carefully the relative cost of efficient sanitary measures and precautions, and of the awful sickness and wide-spread misery resulting from the want of the same; let him read the accounts of the various campaigns and expeditions of the British* and other armies; of the enormous invaliding and mortality in former days from pulmonary tuberculosis in the army and navy; of the diseases due to unhealthy trades and occupations; of the cost of epidemics of cholera, small-pox, etc., in European towns; and having done so let him honestly confess that the bad effects thus produced, both morally and physically, and the actual pecuniary loss thus resulting, are infinitely greater than they would have been had those in authority been a little less 'penny wise and pound foolish.'

Such a mistaken policy is bad enough, but there is a worse

* Not omitting a comparison of the mortality and invaliding of recent expeditions, where the Sanitary and Medical precautions have been efficient or the reverse.

form of obstruction, and that is where, under an excuse of excessive sanitary expenditure or a plea of greater emergency, local bodies are enabled successfully to block all important proposals for hygienic improvements, in favour of the execution of other works which will redound more evidently to the fame of the proposers or, possibly, lead to the more solid advantages resulting from the bestowal and receipt of contracts. More than this, the question of self-interest at once arises, and a landlord who owns half a street of damp and defective houses, a tanner whose wealth is represented by heaps of noisome and foul-smelling hides, or a person who considers his front verandah the proper place for keeping his cows and ponies, are not likely to be enthusiastic with regard to bye-laws and regulations framed with the direct object of interfering with their free license in spreading dirt and disease. Such cases occurred, and do occur, only too freely in all countries, and constitute a form of obstruction to counteract which requires the strongest determination and most fearless courage of all concerned in sanitary administration. It is for this reason that it has been found necessary in England, after many years of trial of different plans, to make the local sanitary authorities as independent as possible, and to ensure that the medical officer of health, the sanitary inspectors, and other officials shall not be obstructed in their duty by fear or favour of any man.

The only objections to hygiene having any pretension to the attribute Scientific are, first, the assertion that by rendering the conditions of life more healthy, the diseased or deformed who would otherwise perish are kept alive, to the detriment of the future race, and second, that as a result of the lessened death-rate an excessive degree of over-population, and the misery resulting therefrom, are brought about. The first of these was well discussed by the late Surgeon-Major McNally, in the introduction to his hand-book, and the falseness of the proposition involved so clearly shown therein that no apology is required

for reproducing the passage here. "A partial application of Darwinian principles has led to the conclusion* that sanitation interferes with natural law, and that degradation of the human race must be the result of a suspension or abrogation of disease as a cause of natural selection and the survival of the fittest. It may be pointed out that this objection would apply to curative more aptly than to preventive medicine. Its confutation, however, must rest upon evolutionary principles. The fact is certain that insanitary conditions affect not only the weakly, whom they kill, but the strong, whom they debilitate, and, in this way, they tend to produce a depraved race; whereas improvement in sanitary conditions, according to the doctrines of the influence of environment and improvement under improving conditions, must tend to improve the race. It might be conducive to improvement—unless the race were totally wiped out by the process—if individuals attacked by diseases which permanently enfeebled them were all to die, and thus be prevented from propagating a feeble offspring; but it is a fact that, for each one who dies, a considerable number recover with more or less damaged constitutions; such diseases being unchecked must, therefore, necessarily tend to cause degeneration of the race. On the other hand, the aim and effect of sanitation is to prevent the enfeeblement of individuals by disease, and not only to act thus, in a negative way, by preventing deterioration of the race, but also to act positively towards the improvement of the race by improving their surroundings and their mode of life. Practical illustrations of the truth of these doctrines may be observed everywhere. Persons and communities who live under the best sanitary conditions are notoriously the most vigorous; those who live in the country are more vigorous than others of the same race who live in towns under inferior sanitary conditions; those who live on high lands, where the soil is comparatively dry and the air and water pure, are more

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* A conclusion which has partly been supported by the great authority of Herbert Spencer.

vigorous than those who live on ill-drained low lands; the unhealthy life conditions of the inhabitants of malarious tracts in South Canara and the Wynaad have produced a puny, stunted, short-lived and degenerate race, who compare unfavorably in every way with the inhabitants of healthier localities in the neighbourhood. Drainage and improved ventilation have enormously reduced the prevalence of scrofula in many parts of England to the obvious benefit of the race. From these and innumerable other examples of the kind the conclusion is inevitable that the aim of the sanitary evolutionist should be not to deprave the race by adapting it to unhealthy surroundings, but to elevate it by improving its surroundings."

The second assertion is certainly deserving of far more careful consideration than it has yet received. It is undoubtedly a fact that in Great Britain, where the benefits of applied hygiene have had fullest play, the population is increasing by leaps and bounds, in spite of a diminished birth-rate, and at the same time is tending more and more to concentrate itself in the large towns. This subject has been already alluded to, and in one sense is a matter for congratulation; but it is evident that there must be a limit so far as any one country is concerned, and in the case of Great Britain that limit will very soon be reached.* The accompanying extract† will show that this is not a fancied danger looming in the dim future, but is one which even now has assumed no mean proportions.

"Let the reader endeavour to form a mental picture of London multiplied by three. If the gruesome spectacle thus conjured up does not make him shiver, he must be either very callous, or else endowed with an enviable amount of optimism."

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* A mass of interesting information on this and kindred matters of the most vital importance to the student of hygiene will be found in a lately-published work, *Studies in Statistics*, by Dr. G. B. Longstaff, which should be studied by everyone interested in the social and economic problems of the day. *v.* also, Newsholme, *op. cit.*

† From an instructive paper, entitled *Overcrowding*, by that eminent hygienist, Dr. Greene Pasha, *v.* Medical Magazine, Vol. I., p. 1036.

"The following short statement may serve as a foundation for the representation :—

Population of London, 1892 = 4,263,294.

Weekly increase, 870 = 45,240 per annum, or 1·06 per cent.

An increase of one per cent. alone would in 100 years suffice to bring up the total to 11,531,328.

Allowing for the decimal, but taking no account of immigration, the London of our grandchildren will in round numbers contain 12,250,000 inhabitants.

It must be borne in mind that this fearful array of figures refers to the Metropolis solely. In rural England, generally speaking, the death-rate is lower and the birth-rate higher than in London; but supposing, for the sake of illustration, that the movement of population should be identical in both metropolitan and country districts during the next hundred years, our descendants at the end of that comparatively short period will find themselves struggling for air and food in the midst of a compact phalanx of their fellow-sufferers—all more or less starving—amounting, for England and Wales, to upwards of eighty millions."

"The horror of the tragedy embodied in this picture is so great that further amplification could scarcely add to it. In order, however, that the reader may have no doubt on the subject, his attention is directed to a few more unassailable facts, which unhappily only deepen tints already far too sombre. According to the Census of 1881, the population of England and Wales was 25,974,439, or in round numbers, twenty-six millions. In 1891 it had risen to over twenty-nine millions, being an increase at the rate of upwards of 300,000 per annum. This represents a percentage of 1·16 against the London rate of 1·06. Instead of eighty millions, therefore, the population to be dreaded is really ninety-one millions."

That this is a question urgently demanding the attention

of legislators is a matter that admits of no question.* Of its ultimate solution there can also be no doubt, but by what means, whether through continued immigration to every habitable and cultivable quarter of the globe, and through the adoption by the more enlightened peoples of strict laws regarding the non-marriage of those in any way physically or mentally unfit, or through a recrudescence of dire pestilences and famines in certain quarters, or, finally, through fierce and protracted struggles between contending nations with the accompanying slaughter of human beings on a gigantic scale, there is no knowing. It is possible that within the next one hundred years mankind may have realised practically the uselessness and horror of warfare, and that the peace and security resulting therefrom may enable them to give their undivided attention to the peaceful arts; so that with true hygiene in their midst, taxation reduced to a fraction of the present burden, and ample leisure to develop the material resources of the world the cost of living may cease to be the chief concern of life, and all men may have time to devote their attention to the due and sufficient cultivation of their bodily, mental and spiritual faculties. Then, at length, will the Golden Age—sung of by poets and dreamt of by dreamers through countless years—have dawned upon the children of men, whose lives are now but too frequently a record of sorrow and disease from the cradle to the grave. Whatever may be the final solution of this problem it still remains the duty of the hygienist to further by every means in his power the cause of the public health, but he must also recognise and study those other social questions which have arisen and will continue to arise as the future history of the human race is day by day and year by year unrolled.†

In the light of what has been said as to the gradual

* It must be remembered that though Great Britain and its capital, London, are specially alluded to here, the question of over-population and its fearful evils is also applicable, or soon will be, to the whole of the civilised world.

† *v. post.*

development of hygiene from ancient times until now, and especially as to the enormous progress made during the last fifty years in all its branches, from preventive medicine to sanitation, progress which had raised it definitely and permanently to the position of a leading science, let the student turn his attention for a little to the work already accomplished in India in this direction.* Previous to 1858, the year in which the Hon. E. I. Company handed over the care of British India to the Crown, sanitation had received but scant attention. Thereafter, as before noted, the Royal Commission on the Sanitary State of the Army in India was appointed and, as a result of its labours and report, attention was forcibly directed to the absolute neglect of all sanitary principles throughout the country generally, and the enormous amount of disease and high rate of mortality thereby ensuing.

In this connection it is interesting to note the great change that has already been wrought with regard to the health of Europeans in India. At the beginning of this century, and for many years after, the mortality amongst the European settlers, from a variety of causes, was fearful, and doubtless exceeded considerably that of the native population. Speaking of Bombay, one writer said, "I reckon they walk in charnel houses; in five hundred, one hundred survive not." The Europeans in Calcutta used to congratulate themselves on having survived another hot weather and rainy season. The three factors that chiefly contributed to this excessive death-rate were, probably, the extreme unhealthiness of the native population and the universal prevalence of filth and pollution, the disregarding by new comers of the fact that they were living in a tropical climate and under conditions quite different to those to which they were accustomed in Europe, and last, but by no means least, the abuse of alcoholic stimu-

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* Much of the information here given is derived from the interesting and elaborate paper entitled *Sanitary Progress in India*, by Sir W. Moore, K.C I.E., late Surgeon-General with the Government of Bombay. *v*, Trans. VIIth San. Sci. Cong., Vol. XI.

lants. True, many of them tried to adapt themselves to the customs of the country and possibly escaped certain dangers by this method, but on the other hand, as appears from old journals and biographies, they often adopted customs injurious in themselves or unsuited to the ordinary European constitution, *e.g.*, the total abandonment of regular exercise, the taking of large quantities of bulky food at one meal, etc. Since that time, although the general mortality in India remains very high, the health of the ordinary Anglo-Indian has very greatly improved and the death-rate declined in proportion; the chief contributing causes to the above improvement being, (1) the greater facilities in journeying, both by land and sea, whereby unhealthy localities can be largely avoided in travelling, short leave can be spent in the cool, healthy climates of the hill stations, and access to Europe and other countries is rendered easy and rapid; (2) the sensible alterations made in nearly every point relating to personal hygiene, *e.g.*, the adoption of suitable clothing and head gear, the avoidance of heavy meals during the heat of the day, moderation in the use of alcohol, etc.; and (3) the fact that the Anglo-Indian, owing to his own habits being sanitary as a rule, is enabled to reap the advantage of the little (comparatively) that has been done in the way of general hygiene.

As regards the native population of India, the conditions obtaining throughout the land, on occupation by the British, were in many ways similar to those of Europe during the Middle Ages, allowing for certain differences in the eastern climate and customs. The cities were mostly composed of Forts and Palaces, within and around which clustered the various 'bazaars'; whilst the remainder of the population lived in small, scattered villages close to the land they cultivated, or in remote jungle tracts. Of course there were exceptions to the above, especially in the case of places possessing shrines of repute, or with a great name for commerce. Here there was generally a straggling town, irregularly grouped round the

sacred shrine or business quarter, and in and around which at certain seasons enormous multitudes of pilgrims or traders, as the case might be, were wont to congregate. Sometimes, under favourable circumstances, these swarms of human beings would escape any serious calamity, but when exposed to wet weather, scarcity of food, pollution of the drinking water, or other defective sanitary conditions, disastrous outbreaks of disease would occur and decimate the local population and the camps of the strangers. The old custom of protecting a town from sudden surprises from without still survives in the form of the hedges of prickly pear or aloes, etc., which are seen surrounding so many Indian villages, and which, like the mud walls and hedges around each individual village hut, are but too invariably the receptacle of every kind of filth and excrementitious matter, and also oppose a very efficient barrier to the perflation of the village lanes and bye-ways by the light breezes that prevail for many months annually.

To the insanitary state of the towns and villages at the time of the British occupation, as above-noted, must be added the important fact that owing to the unsettled condition of affairs the inhabitants of many districts were liable to attack at any time from hostile invaders and, in the event of defeat, to be either dispossessed of their land and goods, or to be crushed by grievous taxation, from which latter they themselves would derive no single benefit. Following these disasters would probably come famine and its miseries, and on the top of this cholera or other epidemic disease, reducing the miserable people, to whom escape or relief was impossible, to utter despair. Of course this state of matters was not general throughout the country, in many parts of which the people, when sufficient rain fell for their crops, led a careless and happy life, but it is undoubtedly true that this peaceful and pastoral existence was liable to sudden irruptions of human enemies or of more insidious, but not less destructive, foes in the shape of famine and disease.

It is impossible to follow in any order or detail the various improvements which have directly or indirectly contributed to the amelioration of the insanitary conditions formerly prevailing throughout India. Amongst these, however, must be noted the steady and effective pacification of the country, the introduction of law and order generally, in place of injustice and insecurity of life; the opening up of free communication by railways, roads and waterways; the conservation of existing, and creation of new, water supplies for agricultural purposes;* the formation of forest reserves; and many other systems and reforms by which the vital surroundings of the population at large have been greatly improved and ameliorated. Of still greater immediate value has been the establishment of hospitals and dispensaries throughout the length and breadth of the land, whereby not only have countless thousands of sick been benefited, but the timid or sceptical have been forced to realise that they are governed by a nation to whom the life of the humblest outcast is a matter of concern. As in other countries, so in India, there is nothing so convincing of the good intentions of the governing towards the governed, once that initial fears or prejudices have been overcome, as the establishment of institutions to which all alike have access for relief from their burden of sickness and disease. Hand in hand with the establishment of hospitals has gone the building of asylums wherein those mentally afflicted are treated, not as criminals or even as nuisances to the State, but with all kindness and attention. So also with leper asylums; whilst even the criminals are fed, lodged, and looked after at enormous cost and with the greatest care under a system which has deservedly a world-wide reputation for humanity and efficiency. Finally, there must be noted the favourable influence exercised by the spread of general education. And here arises a question which is not so very easily answered in practice,

* With the important reservation that in many places the introduction of extensive artificial irrigation schemes, whilst increasing the local revenues and food supplies, has been the direct cause of districts previously healthy becoming extremely malarious, or otherwise unhealthy, as in Egypt.

namely,—Is it better to introduce sanitary reforms at once and, by improving the general health of the population, to pave the way for the reception of mental instruction, or is it better to educate the people first and then, when they can understand the *rationale* of sanitary regulations and improvements, to make and carry out the latter ? The proper answer to which question is probably the following. The first essential is to spend time and money in introducing at once simple and easily-appreciated sanitary reforms ; follow this up by a sound education, which must include the elements of physiology and hygiene as a *sine quâ non ;* the sanitary reforms being meanwhile steadily continued and increased in number and efficiency. Once that arrangements have been made for securing to all the benefits of a thorough grounding in the *essentials* of education, then hygiene, in the full and modern sense, should take absolute and continued precedence in expenditure, instead of being sacrificed in turn to every other department.*

With regard to the more directly sanitary improvements, a great deal has undoubtedly been done, but the fringe of the subject has scarcely been touched as yet; though many who do not realise the immensity of the problem imagine that the sanitation of India has made great progress. In former times all sanitary work was planned, supervised, and executed officially, with the result that in places where the military or civil authorities took an intelligent personal

* This evil has before been alluded to, and it is a serious hindrance to the development of hygiene in India. Whilst systematic investigation into the causation of disease and the methods of prevention of the same is practically unknown and may almost be said to be actually discouraged, negatively, if not positively ; whilst such work is looked upon as an 'expensive fad'; whilst a presidency capital has the highest death-rate, the filthiest river, the most barbarous and crowded parcherries—it is yet considered more important to devote enormous sums to the up-keep of art schools, technical institutes, 'higher education,' *et hoc genus omne.* By all means encourage these latter in every way, *but not at the expense of the public health and well-being.* It is not denied that these institutions are of great importance to the material progress and welfare of the country, but what is asserted here, and elsewhere, in no ambiguous terms, is that hygiene is of *still greater importance,* and that a city like Madras, insanitary and unhealthy from one end to the other, has no claim to possess such institutions until there is clear evidence that every possible means to make the city sanitary and healthy have been tried.

interest in the matter, a high standard of cleanliness was maintained, whilst in other places little or nothing was done. So far as military stations, cantonments and jails, etc., are concerned, the work is still largely in the hands of Government officials and, as a consequence of the powers possessed by these latter and the constant supervision exercised by them, a cantonment or the 'lines' of a native regiment are almost invariably distinguishable at a glance from the surrounding portions of the town by their orderly and cleanly condition. It is not contended, of course, that the civil population is, or can be made, amenable to the same hard and fast regulations as govern these military and purely official institutions, but it is asserted that faithful and systematic work by the municipal and sanitary authorities, coupled with the devotion to pure sanitation of a due proportion of the local funds, will very materially lessen the commonly existing marked difference between the military and civil portions of a town. The establishment of municipalities was undoubtedly a most important step, and may be said to have been attended with a considerable, and far from discouraging, amount of success. The history of the local bodies in England will demonstrate to any reader how great are the difficulties and abuses to which such a system is certain to give rise, and how obstinately men, of otherwise good reputation, will resist the introduction of rules or measures that clash with monopoly or self-interest. How much more, then, in a country where the idea of local self-government is foreign, where bribes are universally offered and expected, and where bodily and mental apathy are the rule rather than the exception. The following extract* may help to convey some idea of the importance of such a change. "At the onset it was felt that no real progress could be made unless the assistance of the people themselves was secured. It was further considered desirable that municipalities should form the centres from which education in sanitary matters

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* Sir W. Moore, *op. cit.*

should emanate. The first step was, therefore, the establishment of municipalities. A special Municipal Act was passed for the Presidency Capitals about the year 1863, and soon afterwards another Act was passed for provincial towns. Still more recently legislation has endowed these bodies with considerable powers for securing the sanitary improvement of towns and villages, and has placed at their disposal much money for expenditure on that object."

"Before 1871-72 expenditure was centralised in the Supreme Government, and grants were made to local governments on detailed estimates showing the need of each department. Local Governments asked as much, and the Supreme Government gave as little as possible; but certain heads of expenditure, including sanitation, were now transferred to local governments, with fixed annual grants to meet them. In connection with local self-government by municipalities, it should be stated that the latter were relieved in 1882-83 of police charges; the intention of the concession being that more should be spent on sanitation and improvements. Government have also granted loans to some municipalities."

"According to the most recent reports, I find that there are some 755 municipal towns in India, not including the large number of small villages where there are only sanitary boards; but the people living under municipal control comprise only 5 per cent. of the total population."

"The total receipts of all the municipalities for the year 1889-90 was Rs. 3,720,000, including Rs. 806,000 from loans. About 45 per cent. of this was spent on sanitation.* The income is derived from house tax, tax on rentals, octroi duties, bazaar-stall rents, wheel tax, water rates, rents of properties, public garden and park fees. The population of the municipal towns was 14,275,858. There are also numerous district and local boards for the administration of district hospitals, dispensaries, schools, roads, etc. The

* [Sanitation is a word with a wide meaning in Indian reports, and may include anything, from a road leading nowhere in particular to the purchase of *eau-de-cologne* as a disinfectant!]

importance of the work done by all these local bodies may be estimated by the fact that they have at their disposal, according to the last "Moral and Material Progress Report" of India, more than £7,000,000 sterling annually."

In each of the presidencies and larger provinces there is a Sanitary Commissioner devoting the whole or part of his time to sanitation, and under him there are one or more Deputy Sanitary Commissioners, in the case of Bengal, Madras, Bombay, the North-West Provinces, and Punjab. The towns of Madras, Bombay and Calcutta have each a Medical Officer of Health, and Calcutta, Bombay and Karachi have each a Port Officer as well. In addition, there are Sanitary Engineers for Bengal, Madras, Bombay, the Punjab, and Central Provinces. In the larger towns there are also Sanitary Inspectors. Each District Surgeon, in addition to his other extremely multifarious and constantly increasing duties, is also the Sanitary Officer for his own district and is in charge of the vaccination staff as well. Some idea of the amount and frequency of the supervision that can be exercised by these officers, whose hands are already full of purely medical work, can be gathered from the fact that most of the Madras districts range from 5,000—10,000 square miles, with railways few and far between, whilst the district of Vizagapatam, in which the first railway is only now being constructed, is more than 18,000 square miles in extent, and has a population of over 2,000,000! The various duties of these officials, and other details regarding sanitary organisation and administration are discussed in Part V. of this work.

In commencing the sanitary reform of any district or country the most urgent matter is the provision of a pure water supply: following this come the necessity for the systematic removal and disposal of waste matter, more particularly fæcal matter, the improvement of the air supply by attention to both internal and external ventilation,* the

* *v.* pp. 19-20. It should never be forgotten that the first step towards pure air is not ventilation, the widening of streets, etc., but the regular removal of all filth from streets and habitations, and the more abundant use of soap and water by the inhabitants.

drainage of the subsoil when the ground-water level is high, and last, but not least, the improvement of the food supply of the population when, as is so largely the case in India, it is defective both as regards quantity and quality. Of course there are many other points to which careful attention must be given, but when the population of a country has been supplied with pure air and water, when the pollution of the soil has been stopped as far as possible, and the food supply rendered cheap, good and abundant, it may be safely predicted that the health and general conditions of life of the people will have been very greatly improved.

All these important points have received careful attention for the last thirty or forty years, and in the larger towns considerable progress has been made. What has been done and what remains to be done will be found in the various parts of this work. In the paper by Sir W. Moore, before referred to, there are tables showing towns in which drainage systems, pure water supplies and other sanitary improvements have been introduced, and it may be safely asserted that the Government of India, the Local Governments, and their sanitary advisers, are fully alive to the extreme importance and urgency of the work that still remains to be accomplished in this direction. The same cannot be said, however, for the military and civil authorities at all stations. It is with them, after all, that the actual carrying out of orders and the immediate responsibility for the health of those in their charge lies; hence the necessity for constant and fearless sanitary inspections of all towns, cantonments, villages, etc., by trained sanitary officers* who can judge of what has been done as compared with what might have been done, and upon whose reports, according as they are favourable or otherwise, action will

* At the present time the belief that any fairly good medical officer will do for a Deputy Sanitary Commissioner is all but universal in India, and this belief being put into practice by the appointment of medical officers without a single qualification for such posts, as has been done at times in every Presidency, the office of Deputy Sanitary Commissioner, which should be looked upon as reserved for specially selected and specially qualified officers, is regarded by some as a *dernier resort*, in case all other things fail!

at once be taken with a view to remedying defects. But such inspections can only command the attention and respect they should when it is known that the knowledge and ability of the inspecting official are of the highest, and that he is versed in all that appertains to the theory and practice, the science and art, of his special subject. This alas, is not always the case in India, and it is certain that the technical knowledge of hygiene demanded of first class Sanitary Inspectors in England is greater than that possessed by many who are here, often against their will or concern, designated 'Sanitary Officers.'

Put very shortly, the following are the chief sanitary improvements which have, up to the present time, been accomplished in India. But firstly, it must be noted that, with the exception of vaccination, they are practically confined to the towns, and very largely to the towns with a population of over 20,000 inhabitants. Now the number of towns with a population of 20,000 or more is 227, with a total of less than 14,000,000 inhabitants*; leaving a remainder of 1,808 towns and more than 500,000 villages, containing about 270,000,000 inhabitants, to whom sanitation, in any effective degree, may be said to be unknown. The accompanying table† may serve to give an idea of the area, population, etc., which is under the charge of one District Sanitary Officer,‡ with occasional visits from the Sanitary or Deputy Sanitary Commissioner. In the three presidency towns, Calcutta, Madras and Bombay, in Rangoon, and in some of the larger *mufasil* towns in India, very large sums of money have been spent in providing an abundant supply of pure water, and, in some cases, in introducing a partial or complete system of sewerage. In addition, an enormous establishment of sweepers or *mehters*, bullock carts, etc., is maintained for the removal of excreta, town refuse, etc., and in certain towns, notably

* *i.e.*, almost exactly the population living in municipal towns, *v.* p. ciii.

† Compiled from the latest Census Report (1891).

‡ The fact that many of the larger towns possess hospitals or dispensaries in charge of a medical subordinate, who is also nominally in charge of sanitation, in no way affects the essential truth of the above conclusion.

DISTRICT OF MADURA.*

AREA IN SQ. MILES 8,808.

Towns and Villages Classified by Population.

1—199.		200—499.		500—999.		1,000—1,999.		2,000—2,999.		3,000—4,999.		5,000—9,999.		10,000—14,999.		15,000—19,999.		20,000—49,999.		50,000 and over.		TOTAL.	
No.	Population.	No.	Population.	No.	Population.	No.	Population.	No.	Population.	No.	Population	No.	Population.	No.	Population.	No.	Population.	No.	Population.	No.	Population.	No.	Population.
1,948	168,194	932	299,378	566	403,657	363	507,404	143	354,284	100	376,058	38	244,370	8	96,555	3	50,873	1	20,203	1	87,428	4,103	2,608,404

* The average area of a district in Madras, excluding Madras but including the agency tracts, is 6,722 square miles, which is about 300 square miles more than the area of Wales.

Calcutta and Bombay, systematic attempts are being made to dispose of such rubbish in a suitable manner, as explained in chapter IV. In Calcutta, there is that most essential institution, a municipal laboratory, for the analysis of food-stuffs, water, air, soil, etc., and altogether, the city possesses a large and very complete health establishment. Many other points have received attention in these cities, such as the establishment of vaccine stations, the registration of births and deaths, the notification and inspection of cases of infectious disease, the filling up of tanks, the improvement of *parcherries* or *bustees*, the regulation of buildings, of slaughter-houses, of fairs, etc., and other things too numerous to mention, but there remain the facts that, with the possible exception of one or two of the largest cities, the attention given to sanitation and the money expended upon purely sanitary works are by no means what they might be, considering the enormous importance of these matters. It is, however, extremely gratifying to notice that in several of the largest and most powerful Native States in India, this subject is receiving very considerable attention, and much money is being spent on the introduction of sanitary reforms.

That the difficulties of more effective sanitation in India are great, cannot be denied. The various causes of obstruction to improved sanitation common to all countries, or to India in particular, have already been considered, but it is interesting to note here the views of a most capable and experienced medical officer as lately expressed.* "The Government of India has already done a great deal, and when it is reproached for not having done more, it can only plead the enormous extent of the work remaining to be done, and the impossibility of doing it all at once. It is sore let and hindered by two great obstacles,—the ignorance, apathy, and prejudice of the native populations, and the lack of money. The natives, though differing enormously among themselves in race, in religion, manners,

* Surgn.-Colonel R. Harvey, D. S. O., I. M. S. *v.* Trans. Internat. San. Sci. Cong., Vol. XI., p. 104.

customs, and other ways, are unanimous on two points, their dislike of innovation and of taxation. They have for the most part no idea of the benefits of sanitation, nor of the dangers which result from its neglect. What was good enough for their fathers is good enough for them, and it is exceedingly difficult to bring home to them that they derive any personal gain from the expenditure on sanitary improvements. The cry of religion in danger is invariably raised when any innovation is attempted. It was so the other day, when the age of marriage for girls was raised from 10 to 12 years. It was so over schemes for better water supply, over vaccination, over public latrines and other matters. It will take a long time to educate them to appreciate modern ideas on sanitation. A government, and especially an alien government, cannot offend the root-ideas of its subjects; but the Government of India are doing their best. The second great obstacle in the way of the Government is the question of cost. The needs of India are enormous. An income much larger than that available could be profitably spent in developing the resources of the country. A crowd of greedy applicants assail the Government on all sides for grants. Roads, railways, canals, and irrigation schemes, forests, telegraphs, barracks, court-houses, and other public works, to say nothing of periodical famines, and the constant demand of the military authorities for troops, munitions, and frontier defences, would take much more than Government can spare; and all are urgently needed, so that it is hardly to be wondered at that schemes,—the practical advantages of which are not immediately apparent, and the results of which may not be evident till the next census,—which, moreover, are sure to be met with strenuous opposition and protests from the very people intended to be benefited,—should be crowded out in the scramble for Government allotments." So that, although it is hardly to be wondered at that sanitation is "crowded out" in the struggle for allotments, what is wanted is a clearer recognition by all, from greatest to least, that in a country which is fairly settled

there is *no one thing so urgent*, nothing of such supreme importance, as Health, and that the Statesman by whom this belief is strongly held and practised will be the man whose memory future generations will delight to honour.*

Of the actual value of all that has been done under the name of Sanitation in India, it is exceedingly difficult to form a reliable estimate.† In the larger towns the mortality from cholera has been very greatly reduced by the introduction of a pure water supply. Dysentery, formerly a most fatal disease, has to a great extent lost its terrors for those Europeans who live carefully as to diet, clothing, avoidance of chill, etc., whilst even the Native population, particularly those who avail themselves of rational treatment, suffer to a much less degree. Guinea-worm is now extinct in many localities where it formerly abounded. The improved sanitary conditions and vital surroundings now obtaining in India have chiefly, as before noted, been instrumental in improving the health of the European population, and also, to a certain degree, the health of those Natives of India who by wealth or education are enabled to live in somewhat the same manner.‡ Amongst the mass of the people, the conditions of life and personal habits, through poverty or custom,|| are still so completely insanitary that many years must pass ere they can be freed

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* "The great social question which should engage the attention of Statesmen is the health of the people."—Lord Beaconsfield.

† Chiefly owing to the very deficient Registration Returns in India.

‡ *i.e.*, as regards rational sanitary precautions. There is no necessity, actual or implied, to adopt the more distinctive habits of Europeans, as so many, particularly in regard to the taking of alcohol, are doing.

|| A certain municipality in India not long ago gravely carried the following resolution and submitted the same to Government. "The Commissioners disapprove of the following passage in the statement of causes assigned for the excessive mortality * * * .—"To enumerate them . . . . and lastly, the general social, conjugal and religious habits and customs of the people." " They apparently forgot that mere disapproval, or even negation, cannot alter stubborn facts. *V.* also, *Notes on the Hygienic and Demographic Condition of India*, by R. B. Vishram Ramji Ghole, L. M., F. Bo. U., Honorary Assistant Surgeon to H. E. the Viceroy, Trans. VIIth Internat. San. Sci. Cong., Vol. XI. The grieved Commissioners, above referred to, however, may console themselves that neither their town nor their nation is by any means unique in respect that the mortality is increased by the 'social, conjugal and religious habits and customs of the people.'

from the present excessive mortality save, possibly, that resulting from epidemic infectious diseases, which is largely controllable directly by general sanitary measures. Of all diseases Malaria is still by far the most deadly. Out of about 5,700,000 deaths in 1890 from Cholera, Small-pox, Fevers and Bowel Complaints, over 4,000,000 were returned as due to Fever, of which, after making all necessary deductions, at least 75 per cent., or 3,000,000, may be safefy considered to have been caused, directly or indirectly, by malaria.

Having thus indicated, in the briefest manner possible, the essential outlines of the past and present history of hygiene, and having shown the gradual evolution of the science, the difficulties which its supporters have had to surmount, the obstruction wherewith they had, and still have, to contend, the triumphs they have gained, and are continuing to gain, in the fight against disease and misery, it behoves us to examine in detail into the qualifications and training which are necessary for the modern hygienist; and to define the goal towards which all such, who are worthy of the name, are resolutely striving.

The essential qualifications for persons called upon to occupy a high position in the Public Health Service in any country are at least as varied and extensive as those required for any other single office, probably more so. They are primarily divisible into two great classes, *viz.*, the purely technical knowledge, which results from study and experience, and those mental qualities which are more or less necessary to all who aspire to govern or direct public affairs with any degree of success. First, then, as to the exact nature of the subjects with which the hygienist is concerned. Of such, it is impossible to give a complete list here, but some idea of their number and variety may be gathered from the statement that the list should include almost all that is required for the separate degrees in Science, in Medicine and in Public Health. The time has not yet arrived when it has become customary for students

to commence their studies with a view to devoting their future to the pursuit of hygiene, and, indeed, it is still considered by many that the possession of a medical degree is evidence of the possessor's knowledge of hygiene—than which no greater error is possible. No one can now be appointed Medical Officer of Health to any large town or district in England without possessing some sanitary qualification in addition to his purely medical qualification, a step in the right direction*. It was long ago remarked by Lord Herbert that a sanitarian must needs possess a considerable share of the professional knowledge of the physician, physiologist, geologist, meteorologist, topographist, chemist, engineer and mechanic, a list which might now be considerably extended. It is possible that with a few officers thus trained and equipped, particularly as regards the means and methods of research in modern laboratories, the more subordinate sanitary officials might be medical officers pure and simple; provided, however, that they are not already overburdened with other work, and that they have given solid evidence of special training in the essentials of sanitation. The latter should never, on any account, be considered suitable for the purely hygienic appointments, but simply as medical officers who, possessing a sound knowledge of the ordinary sanitation of towns, buildings, etc., are

* For the training of the skilled Hygienist in the future the proper course to pursue would probably be as follows. He should first of all go through the training and examinations for the degree (B. Sc.) in Physical Science as required, for example, by the University of Edinburgh. He should then commence his special training for a special degree, Bachelor of Hygiene. It is without doubt essential that he should be familiar with disease as seen at the bed side, and have a thorough knowledge of anatomy, physiology, etc., but it is absurd to waste his time in the acquirement of a minute knowledge of Surgery and Medicine, Midwifery, Diseases of the Eye, Lunacy, Therapeutics, etc. Instead of such subjects he should be called upon to study Climatology, Demography, Epidemiology, Sanitary Law, Sanitary Engineering, etc., after having passed his examinations in Anatomy, Physiology, Pathology, and especially Methods of Research. He would then be really a trained and skilled sanitary *authority*, competent to give a valuable opinion on proposed sanitary works, to investigate the causes of outbreaks of disease, to offer suggestions of great value to local boards, municipal councils, etc., to work out the cause of specific diseases, etc., etc. He should be neither a medical officer, pure and simple, nor an engineer, but an officer capable of criticising effectively the proposals of both classes. The idea can only be outlined here, but the writer hopes to amplify it elsewhere.

permitted to act as sanitary officers for the time being. To some it may seem that too great insistence is laid on the special training of hygienists and sanitary officers, but the recorded experience of the past fifty years in England and other European countries, the opinions of all whose names are eminent in this connection, the constant expansion and increasing importance of the subject, one and all demonstrate that such training is absolutely necessary and of direct benefit to the public health and public funds alike. The need for specialists in every subject—geology, meteorology, sanitary engineering, medicine, etc.—still remains, but there must be picked men, highly trained and experienced, who are capable of receiving and assimilating the results of the work accomplished by the former, and of judging its value and application in the field of hygiene. For both the hygienist and sanitary officer it is absolutely essential that their training be *thoroughly practical.* Courses of lectures unaccompanied by practical demonstrations are largely a waste of time, and yet the latter appear to be unknown, or at all events unpractised, in India.* The following extract may serve to illustrate what is meant, and also what is needed for students of medicine, for newly-arrived medical officers (the future 'District Sanitary Officers'), for sanitary inspectors, and above all, for candidates for the degree in sanitary science. Of course, the demonstrations would not be the same for all, either as to quantity or quality, it is merely the necessity for analogous practical work in India that is here insisted upon.

THE SANITARY INSTITUTE.

Sixteenth Course of Lectures and Demonstrations for Sanitary Officers, 1893.

Sept. 29. Elementary Physics and Chemistry.

Oct. 3. Ventilation, Warming and Lighting—Sir Douglas Galton, K.C.B.

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* The author has tried to carry out such practical demonstrations to some extent by taking the students of his class to see Sewage Farms, Sewerage Systems, Meteorological Stations, etc., but for various reasons, over which he has no control, it has been found impossible, for the present, to carry on the practice.

Oct. 6. Principles of Calculating Areas, Cubic spaces, etc.; Interpretation of Plans and Sections to Scale—H. Law, M. Inst., C.E.
" 7. Visit to Sewage and Destructor Works—Ealing, at 3 P.M.
" 10. Water Supply, Drinking Water, Pollution of Water—J. Wallace Peggs, A.M.I.C.E.
" 11. Visit of Inspection in the Parish of St. George's, Hanover Square—2 P.M.
" 13. Sanitary Building Construction—Keith D. Young, F.R.I.B.A.
" 14. Visit to Express Dairy Company's Farm, College Farm, Finchley—3 P.M.
" 17. Sanitary Appliances—W. C. Tyndale, A.M.I.C.E. Visit to East London Soap Works, Bow.
" 20. Details of Plumber's Work—J. Wright Clarke.
" 21. Visit to Beddington Sewage Farm—Croydon.
" 24. Sewerage and Sewage Disposal—Prof. H. Robinson.
" 25. Visit of Inspection in the Parish of Chelsea—2 P.M.
" 27. House Drainage—W. C. Tyndale.
" 28. Visit to Isolation Hospital, Museum, Sanitary Depôt, Sewage Disposal works, etc.—Highgate.
" 31. Scavenging, Disposal of House Refuse—Charles Mason.

etc. etc.

If such courses were organised in India, and every medical officer, before being appointed Sanitary officer for a town or district, was compelled to attend, and thereafter examined practically as to his knowledge of the various subjects demonstrated and lectured upon, it is certain that great improvement would take place in many directions, and that many whose interest in hygiene is now of the smallest would be led to devote a greater share of their time and energies to this work. But, let it be remembered that all the knowledge and learning in the world will not transform the student into the true hygienist if he does not in addition possess those high mental and moral qualifications that have distinguished so many whose names are indissolubly linked with the development and evolution of this science. He must have an enthusiasm for the work great and extinguishable, but so completely kept in hand

and controlled that men may not realise the force which is continually impelling them into the paths of health and cleanliness;* still more must he be able to 'possess his soul in patience', not using such as an excuse for idleness, but merely as affording time for the current of public opinion to set in a favourable direction. The man of tact will succeed where the rash or over-hasty will fail, and the best of all is he who, like a wise General on the field of battle, knows just what the forces under his command can do and wherein the strength and weakness of the opposing army lie. And not only is the hygienist engaged in a constant struggle against misery, dirt and disease, but more frequently than not he finds himself in a country where the very inhabitants whom he is seeking to deliver from these tyrants, regard him with dull suspicion or active hatred. To win these doubting or careless ones to his side and to enlist them under the banner of Hygiene; to fight continually and untiringly against all foes to the health of mankind; to consider no labour too great, no matter too trivial for attention—is the work of the hygienic reformer. In a word, he must himself illustrate and amplify the meaning of the Roman poet's saying†:—*Homo sum: humani nihil a me alienum puto.*

What, then, remains to be learnt as to the present position of this science and its expansion in the future? To show this clearly, no better means can be adopted than to lay before the reader a few extracts from the final words of one who has devoted a lifetime to the service of Hygieia.‡

Speaking of the gradual but steady investigation into the varied causes and means of prevention of disease which is now being carried on in Europe, and the application of

* By many, now-a-days, enthusiasm is looked upon as a grand mistake, a weakness to which no man, who is a man, should be liable. Let the student remember, however, that nothing great was ever accomplished without faith and enthusiasm, and, above all things, let him always keep the golden mean between the Scylla of sloth and scepticism and the Charybdis of feverish hurry and fanaticism.

† Terence.

‡ Sir John Simon, K.C.B., whose book, *English Sanitary Institutions*, is by far the most complete history of English Sanitary Science extant, and is worthy of careful perusal by all who study the subject.

the knowledge thus resulting to the control of disease, he says, "The progress which has been made consists essentially in practical applications of Pathological Science; and happily that branch of knowledge shews every sign of continuing to give lessons for application. In the eyes of those who cultivate it in a spirit of becoming modesty towards the magnitude and the difficulty of their subject-matter, it, no doubt, like many other branches of the infinite study of Nature, appears hitherto as only in that first stage of true growth where the known is immeasurably less than the unknown; but even in this early stage it has already given ample light for very large preventions of disease; and, so far onward as we can foresee, we may expect that its light will continue to be an ever-advancing guide for advances of law and conduct. It is now proceeding with such activity as the world has never before witnessed, and the various kinds of knowledge which supply resources for the prevention of disease are increasing with immense rapidity. Clearly we have to hope that, in proportion as exact knowledge is gained of agencies prejudicial to the public health, the nation will provide against them by appropriate law and by effective administration; but, for obvious reasons, it is not likely that practical reforms will keep themselves immediately abreast of scientific progress. For them, namely, the rate of advance must in chief part depend on the progress of popular education as to the facts and interests and duties of the case, and can therefore hardly be expected to be other than gradual and somewhat slow. Thus it has been that down to the present time, our disease-preventive provisions of law have certainly not in all respects kept pace with what we know as to the causes of disease; and even less advanced in most instances is the readiness of persons and authorities to make full use of the provisions which exist.

Even as regards those parts of the case where popular education might now be supposed to have become comparatively ripe—the parts which specially regard the Cultivation of Cleanliness, it would be flattery to pretend that

average England has yet reached any high standard of sensibility to dirt.* Against accumulated obvious masses of filth, against extreme ferocities of stench, local protests no doubt are pretty commonly to be heard, and, at moments when there is panic about disease, may often rise to considerable warmth of indignation; but in regard of the less riotous forms of uncleanliness, far too much insensibility is widely shown.†

"A great people, determining what it will deem to be

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* When I speak of *average*-England still having to learn lessons, and even rudimentary lessons, in various matters of sanitary cleanliness, I do not intend to imply that the wealthier classes of society are an exception to that average reproach. It is by no means alone in comparatively poor and ungarnished dwellings, that filth-diseases and odours of filth are to be found. In the houses of wealthy and self-indulgent persons, who perhaps may be spending money and raptures on the fine arts, and who certainly would think it strange to find themselves under imputation of dirt, and in the highly-paid lodging-houses which these classes inhabit from time to time at their so-called health-resorts, it is not very rare—indeed, as to the lodgings, it is rather frequent,—to find that the staircase is pervaded by more or less sewage-odour from defective drain-structures thereabouts or in the basement; and even the wealthiest know but too well that enteric fever, with its congeners, does not leave them unscathed. Persons, not fairly educated to profit by their sense of smell, stumble as naturally into certain sorts of disease as the more or less blind stumble into other pit-falls.

† See, for instance, how little fastidiousness prevails in the popular mind as to the domestic and commercial arrangements which supply *Drinking Water*. That even the London water-supply, after half-a-century of disgusting disclosures, and after various very terrible disasters, is not yet secured against gross defilement, is a fact to be sufficiently gathered from the reports of the official examiner under the Metropolis Water Act, 1871, and is in other ways deplorably notorious. In the summer of 1886, the *Lancet* medical journal brought to light that, during the week of the Henley Regatta, the Thames, for about a mile's length of its course, were supposed to be sacred to the water-supply of London, had had, on and about its surface, a floating and riparian encampment of some thousands of holiday-makers, using the river as their latrine and middenstead, and with their house-boats purposely closet-piped into it: all this apparently not anything new, but a story which would perhaps strike the popular mind when the medical journal had commented on it! What sentiment of cleanliness prevailed among the thousands who could thus deal with their neighbours' drinking-water, and among the millions who were placidly bearing the outrage, is a question which may be left for such future historians as will discuss the curiosities of English civilisation at the close of the nineteenth century; and in the meantime national education will perhaps have taught that a river, having manured fields and sewage-farms and populous urban districts along its banks, and constituted by law "a navigable highway on which all persons have right to pass and repass for pleasure or profit," is not (even apart from regattas) likely to supply such drinking-water as moderate sentiments of cleanliness would seem to demand.

proper purity for air and water, has not to measure only from the scavenger's point of view, but surely also with some sense of the help which accrues to the human mind from beholding the pure aspects of Nature, and with some readiness for displeasure when the beauty and bounty of Nature are wantonly affronted by slovenliness and waste. For rich and poor alike, it cannot be too clearly understood that the claims of cleanliness are fastidious. In order to sanitary self-protection by its means, there must be sufficient refinement of taste to abhor even minor degrees of dirt, and to insist throughout on the utmost possible purity of air and water; there also must be sufficient sharpness and cultivation of sight and smell, to immediately discover even minute infractions of the sanitary rule; and there must be sufficient intelligence and watchfulness as to the channels, commercial and other, which can clandestinely admit uncleanliness from without."

Again, as regards the progress made since the early part of the present century in the direction of local self-government, more particularly in connection with the Common Health, careful study will show that it has been phenomenal in amount and, in the main, eminently satisfactory. If those in India who are in any way concerned with municipal affairs, indirectly or directly, will but carefully study the historical details of such work in England they will derive from such study an invaluable amount of information and encouragement. "Our last sixty years of English political life have been so transformatory of local administrative relations, that popular intelligence has hardly had time to follow the change, and to realise conscientiously for itself how large a new creation of popular duties and responsibilities has taken place. A period of immaturity in such relations may be expected to have its transient weaknesses, requiring treatment more or less transitory; and, for them, all candid minds make allowance; but, in the more prospective sense which regards permanent norms of action, it of course is supremely to be hoped that demo-

cratised local government will know how to secure due diligence and honesty in the administration of its affairs, without having in any great degree to depend on the punishing powers of Courts of Justice. Surely, far more than on any such exterior corrective, it ought to be able to rely, preventively, on itself; for educated local patriotism can ensure from beforehand, that misdemeanors in local government shall not arise. In this, as in other parts of our electoral system, the high integrity, the dutifulness and disinterestedness of each representative of the people, must be for the people itself to regulate, and, with its respect and gratitude, to reward. Equally, too, the nation is concerned in this correlative hope: that to be elected member of a district, or county-council of local government, and thus to become a participator in functions of essential service to the State, will more and more commend itself, as an object of legitimate and generous ambition, to persons of good business ability and of sufficient leisure, who would have in view no other purpose than that of being actively useful in public duty; and that thus, while true popular education shall be strengthening all electoral bodies to identify and reject the candidatures of persons who are intent only on personal aims, the bodies shall have before them in increasing numbers candidates whom it will be honour to themselves to elect."

"For the further development of our sanitary institutions and their working, the educational onward impulses may be expected to come pretty continuously from members of the Medical Profession, and are perhaps not in any essential sense to be expected largely except from them.* This is not meant only with regard to the abstract science of

* ["The ascendancy of Hygiene has greatened and glorified medicine, without dimming the lustre of any other branch; but though her cult is established, her mission has not ended with the recognition of her supremacy and the faithful following of her own ilk. To day she turns to the people and their rulers, outside the medical fold, and demands the place in their councils that is hers of right. A makeshift share in the administration of the sanitary interest of the country has been grudgingly allowed, but the inexorable demands of modern enlightenment cannot be

the matter, but equally with regard to administration. Regarding the science, it has long been evident enough, that, for such new researches and observations as will supply increase to the body of exact knowledge on which the prevention of disease depends, the world cannot expect much help except from the work of the Medical Profession; and the same is now constantly becoming more and more clear in regard of public sanitary administration. Whether for kingdom, or for county, or for district, the organisation or procedure which purports to *prevent disease* must sooner or later be judged from the medical standpoint,—from the standpoint of question, whether it has attained, or can attain, the *disease-preventive* good which is its professed aim. Thus, more and more, the practice of sanitary administration is having to adapt itself to the experience and judgment of the medical officers engaged in it; and whatever other services may be auxiliary in the matter, the administration, in essence, tends more and more to define itself as a specialty of medical skill. Therefore and for other reasons, the progress of popular education in sanitary knowledge, and in the art of sanitary government, will depend, to an incalculable extent, on the personal influence of the Health-Officers throughout the country; each of whom is virtually authorised to be the

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satisfied until the Conservator of the public health shall sit a peer among the rulers. The minister of war may build mighty engines for destruction and defence, and muster vast armies and navies, which disease can disperse with a weapon so tiny that the eye cannot discover it and no mere military expedient antagonize it. The Minister of Finance may fill his treasure houses with gold and silver by the ton, which can buy human souls' honor, virtue, independence, everything but the boon of health, God's free gift to man, through which alone he can be like His own glorious image. Commerce, agriculture, manufacture, fishery, mining, and all the industrial occupations of the human race, which are the objects of the intelligent supervision of cabinet ministers, who are grand masters of political economy, and social science, cannot thrive without the vigour of human blood and brains and brawn, which are the machinery of these occupations; yet until this decade it has not been thought that the intelligent supervision of a grand master of the divine science of medicine was necessary to preserve this vigour of health of the community, without which even these other ministers can themselves only imperfectly perform their own offices of administration." From *Introductory Address* by A. L. Gihon, M.A., M.D., at the First Pan-American Medical Congress, *v.* N. Y. Med. Journ., 30th September, 1893.]

sanitary educator of his district; and it may reasonably be hoped and expected, that, in proportion as those officers are of attainments and character entitling them to have weight, each of them will be accepted as an influential public teacher, and especially will be encouraged to inform and inspirit for sanitary purposes the local authority under which he acts."

"The fact that Preventive Medicine has now been fully adopted into the service of the State is indeed the *end* of a great argument; and if the institutions of the country are to be valued in proportion as they favour the greatest good of the greatest number, it may be assumed that those which represent the counsels of Preventive Medicine will never henceforth be held in low esteem. There no doubt exist schools of thought, to which this branch of political duty may appear but a trivial and niggling kind of industry. From beside the Main* it has been expounded to us in language equally learned and lugubrious, that the radical error of the universe (next to the fact of its having come to be) is the fact of its preferring not to come to an end; and, in the light of that creed, it may seem an absurd anachronism that even the millions of mankind, whom a late much-respected philosopher of ours used from time to time to describe as "chiefly fools," should be willing to let their existence be prolonged. But however great may be the academic interest of those opinions, there seems no likelihood of their being accepted as bases for national policy; and to minds which have had the happiness of discipline in the Art of Medicine, they will not count as of more practical import than any mere curious wreathing of tobacco-smoke."

Let not the student of hygiene in India despair, therefore, because there seems so much to be done and so few to do it. The lesson to be derived from a study of sanitary reforms in England is one of hope and of great things

* [An allusion to the so-called pessimistic philosophy of Schopenhauer, whose writings contain, nevertheless, some very valuable hints on mental and bodily hygiene.]

accomplished from small beginnings. Let him remember, also, that personal example and influence are of far greater value than mere words. Do not expect to be welcomed as the harbinger of good tidings. By far the greater portion of the human race objects—like a dirty child—to have itself and its surroundings thoroughly clean, and many years must elapse ere true cleanliness becomes the rule rather than the exception. Of the ultimate triumph of Hygiene over the rude and insanitary conditions prevalent at the present time throughout this vast country there is no doubt. Let each take up, as he is able, his share in the mighty work of reformation and shew that he has realised for himself that "cleanliness is next to godliness," and that for the full and proper development of the latter, cleanliness of mind and body, notwithstanding many would-be examples to the contrary, are most absolutely essential. "Meanwhile," wrote one,* "let the Sanitary Reformer work and wait. "Go not after the world" said a wise man, "for if thou stand still long enough the world will come round to thee." And to Sanitary Reform the world will come round at last. Grumbling, scoffing, cursing its benefactors; boasting at last, as usual, that it discovered for itself the very truths it tried to silence, it will come; and will be glad at last to accept the one sybilline leaf at the same price at which it might have had the whole. The Sanitary Reformer must make up his mind to see no fruit of his labours, much less thanks or reward. * * * * But his works will follow him—not as the preachers tell us, to heaven,—for of what use would they be there to him or mankind?—but here on earth where he set them, that they might go on in his path, after his example, and prosper and triumph long after he is dead, when his memory shall be blessed by generations, not merely 'yet unborn', but who never would have been born at all had he not inculcated into their unwilling fathers the simplest laws of physical health, decency and life." And since those

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* Chas. Kingsley.

concluding words of one who spent years of his life in inculcating and practising sanitary reform were penned, the world, or at least the major portion of the civilised world, has in large measure "come round" to an appreciation of the efforts made by these pioneers and to the adoption of the principles so forcibly insisted upon by them. To apprehend these principles and to apply them, to educate and raise the millions sunk in dirt, disease and misery, is the great, but not insuperable, task, the weightiest responsibility of each and all on whom the blessing of education has been bestowed—a responsibility which has received great, and will receive greater, recognition from those who govern, and a task, the ultimate and successful accomplishment of which, demands the untiring co-operation and sympathy of every one whose heart has responded to the cry of suffering humanity.

THE INDIAN

MANUAL OF HYGIENE.

CHAPTER I.

AIR.

Atmospheric air consists of a *mixture* of oxygen and nitrogen, with small quantities of carbonic acid and aqueous vapor, and traces of ozone, nitric acid, ammonia, and marsh-gas or some other combination of carbon and hydrogen. Air is impure when it contains excess of any of its ordinary components or any additional substance.

The normal proportion of Oxygen may be taken as 20·96 volumes in 100. In pure air over mountains it rises to 20·99; in towns it falls to 20·90 or even lower.* Ozone is a modified and more active form of oxygen. It is generally present in the atmosphere, more abundantly at night than by day, and is believed to be beneficial, unless when in excess, in which case irritation of the bronchial passages results. It is absent from the air of ill-ventilated sick-rooms, and is said to be at a minimum during cholera epidemics. It is produced by the passage of electrical discharges through air, and by other means. Its amount is estimated by the degree of blueness given in a definite time to test-papers

* The variations are almost invariably confined to the second or third decimal place, but the air in badly-ventilated mines may contain only 20 *per cent.* of oxygen or even less.

prepared with a mixture of potassium iodide and starch. Other causes, however, are capable of producing the same coloration, and a quantitative test for ozone which can be depended upon has yet to be discovered. It is converted to ordinary oxygen by heat, slowly at 100° C., instantaneously at 300° C.

Ozone is an allotropic modification of oxygen, and its molecule is supposed to contain three atoms, while that of ordinary oxygen contains two. Its density is one-twelfth greater; its power of oxidation superior. Its oxidising powers may be ascribed to its easily yielding atomic oxygen $O_3 = O_2 + O$. When strongly compressed, ozone liquefies and forms a deep blue liquid and the gas itself has a blueish tinge. All the processes of Nature which develope electricity by friction, chemical action or otherwise, generate ozone. Its presence in considerable quantity is attended with a peculiar pungent odor, as when the electric spark is passed several times in succession through air, and from this fact its names is derived. The oxidation of the essential oils of odoriferous plants is also supposed to cause the evolution of ozone. In most cases the development takes place only under the influence of sun-light, but it also occurs in the dark. The cultivation of aromatic and flowering plants about unhealthy places is, therefore, indicated.

Nitrogen is not directly poisonous, and slight excess of it, which may occasionally and temporarily exist, is not injurious. The average proportion may be stated as 79 volumes per 100.

Carbonic Acid varies in amount, in pure air, from 0·2 to 0·5 volume in a thousand. The average is taken at 0·4 and the quantity is excessive when it exceeds 0·5.* The proportion increases as we ascend from sea-level to a height of 11,000 feet, diminishing above this elevation; it is less over sea than over land, and is greater in sea-air by day than by night, the difference being from 0·054 to 0·033 per cent. It is diminished by heavy rain, which washes it out of the atmosphere, by vegetation and by strong winds. The ordinary causes of excess of carbonic acid in the atmosphere are the respiration of animals, the exhalation from their skins, combustion, putrefaction and stillness of the air. It is, therefore, more abundant in densely populated

* This amount of CO_2 is not *in itself* injurious; it is considered to be excessive because it has been ascertained that there is a constant ratio between the amount of CO_2 present and of organic exhalations, and that when the CO_2 exceeds 0·5 volumes *per* 1,000 there is almost always an injurious amount of organic impurity in the air. *v.* pp. 11 and 21.

districts. The mean of 18 determinations by Dr. A. Smith of carbonic acid in the air of close places in London was 1·288 volume per 1,000, the maximum 3·20. In a crowded school-room Pettenkofer found 7·23 per 1,000. Respired air contains 40 volumes of carbonic acid in a thousand, an adult man at ordinary labor giving out from his lungs from 12 to 16 cubic feet in 24 hours.* An undetermined quantity is exhaled from the skin of living animals.

A given volume of coal-gas produces, when burnt, about twice its bulk of carbonic acid. The combustion of a pound of oil generates nearly as much as 10 cubic feet of gas. A pound of dried wood requires 120 cubic feet of air for complete combustion, the principal product being carbonic acid; and a pound of coal requires twice as much.

Putrefaction consists chiefly in the slow oxidation of organic matters through the activity of micro-organisms, by which, amongst other changes, carbon is converted into carbonic acid. This gas constitutes 16 per cent. of the emanations from sewage, and sometimes 2 or 3 per cent. of sewer-air. The atmosphere of burial-grounds has been found to contain from 0·7 to 0·9 volume per thousand, and that of marshes from 0·6 to 0·8 or more. The effects of breathing air containing excess of carbonic acid vary, not only with the quantity present, but also with individual peculiarities. In some persons 15 to 20 volumes per thousand produce severe headache, while others can inhale with impunity air containing a much larger proportion. The fatal dose ranges between 50 and 100 volumes per thousand. It is probable that a much smaller amount than 15 per thousand produces a degree of discomfort indicative of incipient intoxication. It is difficult to ascertain the effect of excess of carbonic acid alone. In respired air organic matters and other deleterious gases are present also, and are answerable for much of the injurious result of its inhalation. In manufactories of aërated waters air containing 2 volumes per thousand of carbonic acid is breathed without mischief; but respired air containing one volume produces perceptible ill-effects, and if from 1·5 to 3 be

* v. p. 20 and p. 23—note.

present, headache and vertigo result. It has been conjectured that inhalation of air containing excess of carbonic acid is a common source of phthisis, but the facts which appear to support this view relate to air vitiated by all the products of respiration, not by carbonic acid only. The ill-effects of the latter are only partly due to direct intoxication. Its presence in excess diminishes the supply of oxygen to the blood, and impedes effective elimination of carbonic acid from the lungs. The estimation of the amount of carbonic acid present in the atmosphere is effected by means of a solution of lime or baryta of known strength. A certain quantity of the solution being agitated with a known volume of the air to be examined, the carbonic acid of the latter forms a carbonate with the base, diminishing proportionately the alkalinity of the solution. *The loss of alkalinity is, therefore, a measure of the carbonic acid present.*

The quantity of Aqueous Vapor varies from 10 per cent. of the amount necessary for complete saturation upwards. Air absorbs moisture from water with which it is in contact; respired air is saturated with watery vapor, and the lungs and skin of an adult exhale from 25 to 40 ounces of water in 24 hours; water is one of the products of the combustion of ordinary fuel. The hygienic effect of dryness or humidity upon health, and the proportion of atmospheric moisture most favorable to health are not known. The latter has been supposed to be from 65 to 75 per cent., but many healthy climates exhibit a much higher degree of humidity than this. The amount present may be ascertained by drawing a known volume of air through a tube containing pieces of pumice-stone moistened with strong sulphuric acid, which deprives the air of its water, and weighing the tube before and after the process. The increase of weight represents the quantity of water present in the known volume of air. Hygrometers or comparison of two thermometers, one with a wet bulb and the other under ordinary conditions, enable us, with the aid of tables,

to determine the amount of aqueous vapor in the atmosphere at any particular time. The processes will be explained hereafter.*

Traces of NITRIC ACID are always present in air, and more distinctly after heavy rain and electrical disturbance. It has no influence upon health. It may be detected and estimated by applying to rain-water, or to distilled water through which a given volume of air has passed, the appropriate tests; which will be referred to under the analysis of Water.†

Traces of AMMONIA also are present in pure air, and the quantity is increased after heavy rain: as a rule, however, the ammonia is in combination with nitric, carbonic or some other acid. When moist animal matters, containing both nitrogen and hydrogen, decompose, ammonia is formed. Nascent hydrogen, derived from water resolved by any means into its constituents, unites with atmospheric nitrogen to form ammonia. It is one of the products of the combustion of coal. It never occurs in sufficient quantity to be directly hurtful, except, perhaps, as an irritant of the conjunctiva; but its presence in abnormal amount indicates the existence of danger from other substances directly noxious. Sewer-air and the liquid which collects on sewer walls are often alkaline from ammonia. It is present in excess in the atmosphere of burial-grounds, and occasionally in that of marshy places. The presence of ammonia in the air may be determined by drawing the air, by means of an aspirator, through pure distilled water and applying the Nessler test to the latter.‡

IMPURITIES.

IMPURITIES of the air are either Suspended (Solid) or Diffused (Gaseous). An immense number of substances of all kinds are constantly passing into the air, more especially

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* *v.* Meteorology.
† *v.* Water, Examination of.
‡ *v. ibid.*

in the case of large cities. These impurities are necessarily inhaled to a considerable extent by persons during the act of respiration, but so perfect are the arrangements by which Nature tends to purify the air that the injurious effects produced are surprisingly small. As a rule it is only when such arrangements are thwarted or neutralised by human perversity that serious diseases are produced by these impurities. Thus, careful examination shows that the air of the open spaces or *maidan* in the largest towns is nearly as pure as sea or mountain air whilst the air of Manufactories, Workshops and even dwelling houses is often extremely impure. Suspended impurities may be either Inorganic (Mineral) or Organic (Animal or Vegetable).

Inorganic solids are derived from the soil or sea, from buildings, and from the materials with which certain employments are concerned. Minute particles of flint, clay, carbonate and phosphate of calcium, ferric oxide, of carbon, tarry matters and sulphur, (arising from imperfect combustion of coal or wood), are raised from the surface and kept suspended in the atmosphere. Chloride of sodium, derived from the sea or the soil, is almost invariably present. The air of coal mines, of potters' workshops, of rooms where steel instruments are ground, of stone-cutters' yards and of other places where the nature of the work involves the dispersion of fragments of mineral matter, becomes more or less impregnated with inorganic impurities. Organic suspended matters are more numerous, more varied and more dangerous. Winds raise dust from the soil which is found to contain from 36 to 46 per cent. of organic matter. Evaporation from the surface of water, especially in marshy places, raises minute organized particles into the atmosphere. Thus the remains of dead animals and vegetables, minute living organisms, as vibrios, bacteria of all kinds and other micro fungi, infusorious, ova of various animals, pollen, spores and seeds float in air comparatively pure. In sewer-air meat and milk are tainted rapidly, owing to

the abundant presence of low forms of animal and vegetable life. Starch-cells, hair, wool, cotton-fibres are also present, especially in dwellings, and more abundantly where manufactures of bread, clothing, &c., are carried on. Pus-cells and epithelium, excretions, cutaneous, pulmonary, urinary of fæcal, dried and pulverized, will abound in the atmosphere of dirty and ill-ventilated houses, and in ill-kept hospitals more particularly : the nature and amount of each impurity being in direct ratio to the cleanliness and efficient ventilation of the buildings or the reverse.

Suspended atmospheric impurities act injuriously upon health in several ways. The pus-cells of ophthalmia may float from affected to healthy eyes and communicate the disease. Certain parasitic skin-diseases, erysipelas and hospital gangrene, perhaps metria, may also be propagated by germs or by direct local action of organic poisons so conveyed. The poison of typhoid may thus reach the intestinal mucous membrane and act. The lungs or nasal mucous membrane may be mechanically irritated by particles of mineral matters, or by fibres of cotton or wool, and bronchitis and other pulmonary affections or coryza ensue. The blood may be poisoned by air inhaled containing the specific virus of cholera, typhus, typhoid, paludal fevers, dysentery, variola, scarlatina or measles. Phthisis possibly, the pleuro-pneumonia of cattle certainly, may be propagated by sputa. Whether diseases are propagated by living germs or by dead animal poisons the morbific cause may enter the blood through the lungs.* Again, suspended impurities, except the very lightest, are not likely to reach the lungs, but will lodge on the mucous membrane of the nose, the fauces or the mouth, and pass thence by deglutition into the stomach and intestines. Here they may set up dyspepsia, &c., by local irritation, or they may propagate specific diseases through the intestinal tract.

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* The condition of the organic substances which cause specific diseases is unknown. They may act directly as thrown off from a diseased surface, or after undergoing putrefactive changes.

When maladies, not pulmonary, are due to inhalation of foreign matters suspended in the air, these more probably act by being swallowed than by entering the blood through the lungs. This is true not only of diseases due to organic poisons, but also of the saturnine, mercurial, cuprine and arsenical intoxications, to which painters and plumbers and workmen employed with mercury, copper and arsenic are liable.

Air containing much organic matter blackens sulphuric acid through which it may be drawn, and reddens a solution of silver nitrate. The nature of suspended impurities is ascertained by the microscope. For collecting them two methods are available. A vessel of known capacity is filled with water which is allowed to run out below while an aperture above, to which a funnel with its neck drawn into a fine tube is fitted, admits the air. Below the opening of the funnel a slip of glass moistened with glycerine is fixed, which catches the solids suspended in the air as it enters. Or a known volume of air may be drawn through distilled water and the sediment collected.

The remedies for this form of impurity are heat, corrosive disinfectants, filtration and ventilation. Cotton wool intercepts all foreign substances suspended in the air drawn through it, and respirators made of this material are capable of protecting efficiently persons engaged in employments which disperse solid particles in the atmosphere, and all who are liable to diseases dependent upon the inhalation of solid morbific material. The nasal passages, to a certain extent, filter the air which passes through them and the unnatural habit of breathing through the mouth should, therefore, be avoided. Ventilation will be considered hereafter. It is only necessary to remark in this place that *topical* ventilation—bringing a strong stream of air to bear upon the immediate neighbourhood of tool-grinding and similar machines—has been attended with results most favourable to the health of the workmen. Natural processes tend to keep down the amount of sus-

pended impurity. The heavier substances spontaneously subside. Rain washes others to the earth or carries them down in solution. Part of the organic matter is gradually oxidized into carbonic acid and water or other gaseous substances.

The chief DIFFUSED impurities of air are: organic vapors of unknown composition, carbon dioxide when exceeding 0·5 per 1000 parts of air, carbon monoxide, marsh-gas, sulphuretted hydrogen, sulphide of ammonium, sulphurous and sulphuric acids, carbon disulphide, hydrochloric, nitrous and nitric acids, and phosphide of hydrogen. Of these the most important, because the most injurious to health, are Organic Vapors of unknown composition, and probably of many different kinds. Some properties of these substances render it even doubtful whether they are aëriform or solid. They do not appear to be diffused like true vapors, but seem to float in clouds in foul atmospheres, and the offensive odor which is characteristic of them is not equally prevalent in all parts of a room in which they have been generated. They resist oxidation longer than other impurities, and therefore require freer and more prolonged ventilation than they. It is probable that they are either in combination with, or in solution in, aqueous vapor; as substances which most readily absorb water (hygroscopic), or condense it upon their surface, are found to collect most abundantly the organic products of respiration. The color of the absorbent material is said to influence the amount of organic matter absorbed; black objects collecting most, then blue and yellow, white least. The decomposition of organized structures gives rise to organic vapor; but the most important source is the exhalations, cutaneous and respiratory, of men and other animals. Putrid organic vapor exists in the air of sewers and of burial-grounds, but that which accumulates in ill-ventilated and crowded buildings is more abundant and more noxious. The quantity of organic matter given off from the lungs and skin of an adult man is considerable but has not been deter-

mined,* the organic products of the skin being suspended, those of the lungs vaporous.† In hospitals and rooms where sick or wounded persons lie organic exhalations are still more abundant. To the ordinary products of respiration increased cutaneous exhalations are added, and effluvia from various excretions.

It is not possible to isolate the effects of inhalation of organic vapor from the other consequences of breathing air contaminated with sewage emanations or with the products of respiration; the general effects will be mentioned hereafter. Of the complex poison of respired air the organic vapor is the most active ingredient, and those symptoms which cannot be traced to deficiency of oxygen are chiefly due to it. In cases where death has resulted from overcrowding, without absolute exclusion of fresh supplies of air, organic vapor has probably been the cause. The peculiar fœtid odor of organic vapor exhaled from lungs and skin enables its presence in occupied rooms to be detected. Barrack-rooms, jail-wards, school-rooms and rooms where crowded meetings have been held are likely to present this conclusive evidence of insufficient ventilation. Few hospitals are free from it (though all may be and ought to be), the productive causes being more active in them than in other buildings. The odor is too often perceptible, in barrack-rooms for instance, by day; but suspected quarters should be visited in the early mornings after the full number of inhabitants has occupied them for some hours. It is to be remembered that the inmates themselves are unconscious of the fœtor; that it is more perceptible in proportion to the purity of the atmosphere from which the inquirer has passed in; that breathing foul air impairs, and gradually destroys for the time, the

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* Dr. Angus Smith estimates the animal matter in *respired* air at 3 volumes per mille, in the form of putrescible albuminoid substance.

† The following numbers represent, with reference to the quantity of "organic matters" present, the comparative purity of different atmospheres, as determined by Dr. Angus Smith :—pure air on high ground 176 and 209; in a bed-room 56 and 64; inside a house 16; in a closely packed railway carriage 8; in a house sewer 8; in a cesspool 0·062.

perception of its foulness, and that this sensibility is not immediately restored on return to purer air; and that ability to perceive lower degrees of this peculiar taint is capable of cultivation by practice. *Organic vapor of this kind being generated simultaneously with carbonic acid, the quantity of the latter arising from respiration affords a means of roughly estimating the degree of contamination by the former.* Much carbonic acid usually implies the presence of much organic vapor and *vice versâ,* but not invariably so. When the atmosphere of a room, previously pure, becomes gradually vitiated by respiration, the organic fœtor is easily perceptible when the carbonic acid rises to 0·7 volume per mille, and very strong when the proportion amounts to 1·0. More accurate means of determining the quantity of organic matter present in the air are supplied by the potassium permanganate test and the process of conversion of nitrogenous impurity into ammonia—a known volume of air being drawn through distilled water.

Carbon Monoxide or carbonous oxide is one of the products of combustion of coal and wood. It is capable of passing through the heated walls of iron stoves, less freely through wrought than through cast iron, and its passage is impeded if the stove be lined with fire-clay. Air containing less than five volumes per 1,000, breathed by a small animal, produces symptoms of poisoning, and if more than 10 be present it proves rapidly fatal. It enters the blood through the lungs, displacing an equal volume of oxygen, and can only be removed gradually after oxidation and conversion into carbonic acid. The red globules of the blood become incapable of their function of carrying oxygen to the tissues. Consciousness is lost, reflex action destroyed, atony of the vessels produced, diminishing vascular pressure, causing retardation of the circulation and finally paralysis of the heart. The inhalation of this gas is found to produce very rapid parenchymatous degeneration of all the muscles and of the solid abdominal viscera. The so-called 'water-gas,' now largely used as a heating

agent in America contains 30-40 per cent. of carbon monoxide and many cases of poisoning have already occurred from the escape of this gas by leakage.

Marsh-gas or light carburetted hydrogen is a product of the decomposition of organic matter, and constitutes 73 per cent. of the gases emanating from London sewage. It is generally found in the air over marshes, arising from the putrefaction of vegetable substances. It is a principal constituent of coal-gas. In small quantities it does not appear to produce any ill-effect, and air containing as much as 200 or even 300 volumes per mille may be breathed for some time with apparent impunity. In larger proportion it produces headache, vomitting, convulsions, stertor with dilatation of the pupil and death. Habitually breathed even in small quantities it can scarcely fail to be injurious.

Hydrogen Sulphide results from the putrefaction of organized substances containing sulphur; and also from the action of organic matter on sulphates dissolved in water, which are converted into sulphides, these being decomposed by animal or vegetable acids: it is also an occasional product of combustion of coal and wood. Hence it constitutes sometimes 2 or 3 per cent. of sewage emanations and may amount to 3 per cent. or more of sewer atmosphere; it is found in the air of marshy places, especially of salt-marshes, as those of Singapore; it is present in the foul holds of ships,* and in the smoke of brick-kilns. It is invariably present in coal-gas and rarely in less proportion than 0·3 per cent. There are great uncertainty and conflict of opinion as to the effects of this gas upon the system when inhaled. Breathed undiluted it destroys life at once. Injected in solution directly into the blood it produces the same train of symptoms as putrid animal fluids —profuse diarrhœa, sometimes resembling cholera in the loss of animal heat and general collapse, congestion of the

* Grain saturated with sea-water becomes highly offensive from this cause chiefly: and in a recent case a man employed in clearing a wrecked vessel of putrid rice died poisoned or asphyxiated.

lungs and abdominal viscera, irritation of the spinal cord and opisthotonos. In the smaller doses of inhalation, however, the lower animals, as dogs and horses, suffer from diarrhœa with prostration of strength when the atmosphere contains from 1·25 to 4 volumes of this gas per 1,000: while men have breathed as much as 29 per mille, for a short time, with impunity. In ordinary cases, where inhalation has been continuous but the proportion small, effects have been contradictory: some persons suffering, others remaining apparently unaffected. The intensity of malarious intoxication in some Italian marshes has been attributed to the admixture of sulphuretted hydrogen in the air; while others have supposed it to have a neutralizing effect upon malaria. The symptoms of chronic poisoning seem to be weakness, anorexia and anæmia. In acute cases the symptoms are sometimes narcotic, sometimes convulsive. The characteristic odor of this offensive gas renders its presence, even in small quantities, perceptible. It blackens white paint prepared from lead carbonate, and a slip of white filter-paper dipped in a solution of a lead salt, (as the acetate), is blackened by a quantity too small to be detected by the smell, the black lead sulphide being formed.

Sulphide of Ammonium is derived from the same sources as sulphuretted hydrogen. In large doses it asphyxiates when inhaled; in smaller it produces vomitting without purging, quickness of pulse, heat of skin, followed by collapse. Injected in solution into the blood, its effects resemble those of sulphuretted hydrogen. Its presence is detected by the sodium nitro-prusside which, with this (and the other alkaline sulphides), gives a brilliant purple color.

Sulphurous Acid, Sulphuric Acid, and Carbon Disulphide are products of the combustion of coal and, in a less degree, of wood. Imperfectly purified coal-gas generates, when burnt, the former two, but none of them is of any importance as regards health, their quantity being insignificant. Inhalation of sulphurous acid undiluted is fatal; in small

amounts it produces lacrymation and sneezing; in considerable quantity, bronchitis and ultimately anæmia.

Hydrochloric Acid vapors were formerly given off in large quantities from alkali works in England, the result being the total destruction of the surrounding vegetation. This practice was put an end to by legislative interference. If the vapor is concentrated as in some processes for making steel very serious or even fatal inflammation may be set up in the lungs.

Nitrous Acid is formed by the oxidation of nitrogenous substances and traces of it are frequently present. Phosphuretted Hydrogen arises from the decomposition of organic animal and vegetable matter containing phosphorus. It is found occasionally over marshes and in burying-grounds.

VITIATED AIR.

The effects of breathing an impure atmosphere are found to consist not merely in the production of definite, still less of specific, ailments, but also in an impaired condition of general health, shown by increased liability to, and greater severity of, diseases, protracted convalescence, shortened duration of life, higher death-rate, especially of children. None of the impurities above described occurs singly save only in very exceptional circumstances : as a rule varying combinations of them are found to exist, producing various effects. These must be briefly considered before entering upon the subject of the means by which atmospheric impurity is mitigated or removed. The air of Crowded Rooms or Dwellings contains excess of aqueous vapor and of carbonic acid, as well as the fœtid and exceedingly poisonous organic vapor exhaled from lungs and skin. The effects of breathing such an atmosphere are well marked. A few hours suffice to produce febrile symptoms, hot skin, rapid pulse, furred tongue, anorexia, thirst, &c., and these effects persist for one or more days afterwards. If the intoxication be still more acute, as when the proportion of space to number of living beings is excessively low, asphyxia from

deficiency of oxygen and direct poisoning from organic exhalations combine to destroy rapidly the life of the most susceptible, while the survivors suffer for some days subsequently from symptoms similar to those just described; and the impairment of the vital powers is sometimes evinced by boils. Living habitually in an atmosphere tainted in a lower degree with the products of respiration exercises a most injurious influence upon the general health; often aggravated by want of exercise as in the case of tailors, sempstresses, school-children, &c., by the presence of dust of various kinds in many manufactures, or by idleness and ennui in the case of the soldier. Paleness, with loss of appetite, strength and spirits, shows deterioration of health and consequent inability to resist epidemic or infectious disease. The proportion of phthisis and of pulmonary diseases is higher amongst persons exposed to these unfavorable conditions and the diminution of such affections among soldiers and sailors by improved ventilation of barracks and ships has been marked. Cows, horses, &c., suffer like human beings, and it is well known that the monkeys in the London collection died in large numbers of tubercular phthisis, so long as the arrangement of their quarters was such as to prevent the escape (except by diffusion) of the products of respiration.

The air of sick rooms or Hospitals necessarily contains additional impurities. The proportion of organic matter, both suspended and vaporous, is much increased; producing, unless corrected, not only general impairment of vital power, shown by intensified disease and retarded convalescence, but also specific maladies of which the generating causes accumulate if not removed. Under such circumstances erysipelas and hospital gangrene may be developed and the communication of other infectious diseases favored.

The Products of Combustion rarely accumulate. Breathing the air of close rooms where lamps, especially gas-lamps, are burning, sometimes causes headache and a feeling of oppression, owing to the formation of the oxides

of carbon; and much sulphurous acid arising from the combustion of coal-gas may produce some bronchial irritation. Indirectly combustion may be injurious to persons chilled by passing from a heated room to the colder atmosphere without.

Since the decomposition of animal matter yields carbonic acid, marsh-gas, nitrogen in large quantity, (sewage emanations sometimes containing 10 per cent.), sulphuretted and phosphuretted hydrogen, ammonia and acetic acid; and that of vegetable matter, carbonic acid, nitrogen and acetic acid; Sewer-Air may contain some ingredients which are asphyxiating and others which are directly poisonous. In well-constructed and well-ventilated sewers, however, the air has been shown to be remarkably pure and it is only when deficient in one or both of these important points that disease is directly caused by their presence. The opening of cesspools has thus proved fatal to workmen. Ophthalmia, bilious diarrhœa, and colic have been known to prevail amongst persons employed about sewers. The habitual inhalation of air polluted by communication with sewers produces headache, nausea, diarrhœa, general malaise; and, if continued long, great impairment of health and a state of anæmia. Sometimes brief febrile attacks, characterized by severe headache and derangement of digestive organs, have been observed. Diarrhœa may arise from the emanations from fæcal matters in sewers, especially if the poisonous effects are concentrated by high temperature and drought, which may also assist by rendering the water-supply impure. The connexion of enteric fever with sewer-air is still obscure. It is almost certain that emanations from sewers containing the stools of typhoid patients will undoubtedly produce the disease in persons unprotected by a previous attack. Imperfect sewerage favors the spread of typhoid, improved sewerage has been followed by disappearance of the fever. On the other hand fæcal accumulations may exist for years, and their emanations pollute the air without

the production of this specific disease. It seems probable, therefore, that, as a general rule, sewer-air must contain the specific poison of enteric fever in order to generate the disease; while the possibility of *de novo* origination, through the concurrence of complex and unknown conditions, cannot absolutely be denied. Other diseases, as erysipelas, hospital gangrene, the exanthemata, venereal affections, puerperal fever, &c., have their severity aggravated in an atmosphere tainted by sewer emanations.

The effect, general and special, upon health, of Fæcal Matters accumulated and concentrated in sewers is pernicious, if they are permitted to contaminate the air we breathe; but, when they are scattered upon the surface of the ground, they are comparatively harmless, however disagreeable.* Their emanations are immediately and copiously diluted with ordinary air. Collected in heaps they are nearly as hurtful as in open sewers. Mixed with earth they, in most cases, lose all dangerous properties; though specific poisons, as that of enteric fever, may not be thus destroyed and may propagate disease. Emanations from streams into which sewers discharge excrementary matters will generally be diluted to harmlessness, but the emanations from masses of sewage and mud left bare by the drying up of a stream or tank or by the ebbing of the tide at an estuary are often most disagreeable and dangerous to health.

Residence in or in the neighbourhood of Graveyards is necessarily unwholesome. Although the impure atmosphere may cause no definite disease, it impairs health and diminishes power of resistance to morbific causes. The polluted water of such localities contributes to this result.

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* There is no necessary connexion between a bad smell and injurious atmospheric impurity; some offensive gases and vapors (as sulphuretted hydrogen, ammonium sulphide and organic respiratory vapor) being deleterious, while others, also poisonous, (as the carbon oxides and malaria) are not perceptible by the sense of smell. On the other hand, air impregnated with innocent odors may be exceedingly offensive to the nose.

The decomposition of unburied animals, as in dissecting-rooms on the small scale and battle-fields on the large, sometimes appears to produce bowel-complaints and can scarcely fail to render the air unwholesome always, though satisfactory evidence is wanting. Attendance at funerals appears to have been sometimes injurious to the health.

The air of Marshes, and of other places not *apparently* wet, where organic vegetable matter is undergoing decomposition, produces intermittent fevers and congestion of the spleen with impairment of nutrition and shortening of the mean duration of life. Malarious dysentery sometimes results. These effects, however, are probably due as much to the water of such localities as to the air.

PURIFICATION OF AIR—VENTILATION.

Air is purified by rain which carries dissolved and suspended matters to earth; by winds and currents dispersing and diluting foreign substances; by the vegetable kingdom which, under the influence of light, decomposes carbon dioxide, retaining carbon for its own structures and giving out oxygen; by oxidation of putrescent organic matter; by diffusion of gaseous bodies; by deodorants* and disinfectants*; and by ventilation.

Diffusion is the intermixture of gaseous bodies which do not act chemically on each other and which are either directly in communication or separated by a porous medium such as an ordinary brick wall. Two gases or vapors thus intermixed can be separated only by chemical action or condensation of one of them. The rapidity with which diffusion takes place varies with the difference of densities of the diffusing bodies; the greater this difference, the more active is the process of intermixture.†

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* *v.* Disinfection.

† The diffusiveness or *diffusion-volume* of a gas varies inversely as the square-root of the density; therefore, the time of diffusion (which is inversely as the volume diffused) varies directly as the square-root of the density. As all aëriform bodies may be taken to expand equally under the influence of equal increments of heat, their relative densities are constant

We have seen that the air is constantly being purified by various natural means. In the case of the general air-space of a town advantage is largely taken of such means: by making the streets wide and building the houses not too close together nor too high circulation of the air is unimpeded and a high standard of purity is maintained. This has been called "external ventilation" and it is a most important part of the duties of Municipal Authorities to see that no obstruction of any sort to such external ventilation is allowed to exist. In addition most other impurities can be prevented from entering the air by the watering of streets to lay the dust, by the enforced consumption by manufactories and furnaces of their own smoke and other noxious products, by careful inspection and cleansing of all drains and sewers and by the removal to a special quarter of all offensive trades and occupations. In all large English towns great pains are taken to provide open spaces or parks where the inhabitants of the neighbouring streets and alleys can assemble for physical exercise and be sure of breathing retatively pure air. Such open spaces have been called the 'lungs' of a town. In India nearly every town has plenty open spaces or *maidan*, and in addition the buildings are not so high, but withal the air in the narrow streets and bazaars is often extremely impure, full of dust and filthy-smelling. Every opportunity should be taken by Sanitary officials to secure good external ventilation by the gradual widening of streets, demolition of unused buildings and so on. The term VEN-

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and, therefore, their *relative* velocity of diffusion is unaffected by changes of temperature. The *total* rate of diffusion of equal volumes is increased by increase of temperature, because thereby the densities are diminished; but the rate of diffusion does not increase so rapidly as the expansion by heat. Whence it follows that a given weight of any gas or vapor is diffused more rapidly at a low than at a high temperature. Suppose air and hydrogen to be the diffusing gases, the density of air is taken as unity and its diffusion-volume will be 1, the density of hydrogen is 0·0692 its diffusion-volume $= \frac{1}{\sqrt{0\cdot0692}} = \frac{1}{0\cdot2632} = 3\cdot7994$. Actual experiment gives 3·83. Thus if a body of air and a body of hydrogen are in communication 3·83. volumes of hydrogen pass into the air while one volume of air passes into the hydrogen.

TILATION is usually restricted technically to the means by which the air *in buildings inhabited by men or other animals* is kept at the normal standard of purity and that implies the removal of vitiated air and the supply of fresh air. This is sometimes called 'internal ventilation.' Hence the extreme importance of efficient external ventilation, for upon the purity or otherwise of the outside air depends the possibility of good internal ventilation.*

The points requiring special attention in the study of this subject are. 1. The Rate at which the air becomes impure. 2. The Quantity of pure air necessary to maintain health. 3. The Means of providing the amount required. 4. The Measurement of the supply. 5. The conditions essential to Effective Distribution.

1. The Rate at which the air becomes impure. It will be remembered that normal or pure air contains 0·4 volumes CO_2 per 1,000 volumes of air. To this is constantly being added in dwelling-houses the CO_2 exhaled by the inhabitants and often also the CO_2 which results from the combustion of wood-fires, oil-lamps, etc. Disregarding for the present this latter source of impurity, we can ascertain by direct experiment that *each person gives off on an average* 0·6 *cubic foot* CO_2 *in one hour.* Suppose then one person to be placed for one hour in a room of 1,000 cubic feet, *i.e.*, 10 feet long, 10 feet wide and 10 feet high, and that no fresh air is admitted; at the end of that time the room will contain 0·4 volumes CO_2, (the original amount in the 1,000 cubic feet of air) + 0·6 volume (or cubic foot), *i.e.*, a total of 1 volume CO_2 per 1,000 volumes of air. Suppose now that a person is shut up for one hour under the same conditions in a room containing 3,000 cubic feet of space; at the end of that time the amount of CO_2 present would be ($0·4 \times 3 =$) 1·2 cubic feet CO_2 originally present in 3,000 cubic feet of fresh air, + 0·6 cubic foot CO_2 exhaled by the man, *i.e.*, 1·8 cubic feet CO_2

* In some large buildings, such as concert-halls, etc., the fresh air supply is drawn through a pipe from a distant spot, by means of a revolving fan, owing to the constant impurity of the air immediately outside the building.

per 3,000 or 0·6 volume CO_2 per 1,000. Now in practice it has been found that when the ratio of CO_2 to the air reaches 0·7 volume CO_2 per 1,000 the smell of organic matter begins to be perceptible and injurious effects are produced by the continued respiration of such air. Note accordingly, that the actual amount of CO_2 present is not in itself hurtful but only serves as an *indicator* of the amount of organic matter present. From numerous experiments then a certain standard of purity for the air in inhabited buildings has been fixed, *viz.*, 0·6 volume CO_2 per 1,000 volumes air. From this, however, must be subtracted the 0·4 volume CO_2 per 1,000 normally present in the air and that leaves 0·2 volume CO_2 per 1,000, which has been fixed as the maximum amount of Admissible Respiratory Impurity in well ventilated dwellings.

So, then, if the air of any room contains more than 0·6 volume CO_2 per 1,000 including the CO_2 originally present in the fresh air or more than 0·2 volume per 1,000 excluding the original CO_2 it is said to be impure.

2. Having fixed the standard of purity we have next to ascertain the Quantity of fresh air which must be supplied in order to constantly dilute the air of a room, so that it will not contain more than 0·6 volume CO_2 per 1,000.

a. The amount required for this purpose is always expressed in *x thousands cubic feet of fresh air per head per hour* and is most conveniently calculated from the following formula:

$$F = \frac{E}{R} \times 1{,}000$$

When F = the number of cubic feet of Fresh air required per hour,

E = the amount of CO_2 Exhaled per hour*,

R = the admissible Respiratory impurity.*

* Of course, if we adopt other standards for E and R, *e. g.* E = 0·7 in the case of a room occupied entirely by adults, as in barrack rooms; or make R = 0·3 as is sometimes done; then the amount of fresh air required will be correspondingly altered.

Example.—$F = \frac{0 \cdot 6}{0 \cdot 2} \times 1{,}000 = 3{,}000$ cubic feet of fresh air required in an hour for one person, or for ten people $F = \frac{0 \cdot 6}{0 \cdot 2} \times 10 \times 1{,}000 = 30{,}000$.

b. From this formula used conversely we can calculate the average amount of fresh air which has been supplied and vitiated. Instead, however, of R being equal to the admissible respiratory impurity, in this case it is equal to the Actual Respiratory Impurity as ascertained by chemical examination of the air—say ·8 volumes CO_2 per 1,000.

Then F = number of cubic feet of fresh air per head per hour that has been supplied and utilised,

E = as before,

R = the *actual* Respiratory impurity of the air in the room.

Example.—$F = \frac{0 \cdot 6}{0 \cdot 8} \times 1{,}000 = 750$ cubic feet of fresh air utilised per head per hour.

c. Again, if a given amount of air is supplied per hour to one or more persons in a room, we can calculate the *probable* amount of CO_2 in the air. In such a case E and F are known and it is required to calculate the value of R.

Example.—7,000 cubic feet of fresh air per hour are supplied to and utilised by 10 people occupying one room :* estimate the probable amount of CO_2 per 1,000 volumes of the air in the room.

$$R = \frac{E}{F} \times 10 \times 1{,}000.$$

$$R = \frac{0 \cdot 6}{7{,}000} \times 10 \times 1{,}000 = 0 \cdot 85 \text{ volumes } CO_2 \text{ per } 1{,}000.$$

* In all such cases it is understood that the amount of vitiated air which escapes from the room is the same as that of the fresh air supplied.

From the above formulæ and from practical experiment it has been ascertained that under ordinary conditions the following amounts of fresh air should be supplied per head per hour.

For children	... 2,000	cubic feet per head per hour.
,, Women	... 3,000	,, ,, ,, ,, ,, ,,
,, Men	... 3,600	,, ,, ,, ,, ,, ,,
		(*i.e.*, 1 cubic foot per second).

During work these quantities should be considerably increased and adult men in hard work require about 7,000 cubic feet or more.* Large animals such as horses and cows each require 10,000—20,000 cubic feet of fresh air per hour, which is almost the same as saying they ought to be in the open air.

Hospitals or other places occupied by the sick demand a higher minimum of supply. In some diseases the amount of organic exhalations is so large that it is almost impossible to give pure air enough to remove their characteristic odors. A ward containing many cases with open wounds requires at least 4,500 cubic feet of fresh air per man per hour. When hospital gangrene, pyæmia, erysipelas, typhus, variola or plague prevails the supply of air should be limited only by the necessity of protecting the patients from wet or excessive cold. In such cases free ventilation not only promotes the recovery of the sick but also opposes the spread of disease. It has been observed that the organic poisons of some diseases are more capable of destruction by oxidation, or dilution to harmlessness, by pure air than those of others. Thus, a few feet of freely ventilated space suffice to protect from the poisons of typhus and of plague; while variola and scarlatina spread in spite of abundant air supply, and the diseases are communicable even after months of free exposure to pure air.

* An adult male in hard work gives off as much as 1·52 cubic feet CO_2 in 1 hour, therefore, by formula *a*, ($F = \frac{1·52}{0·2} \times 1000 =$) 7,600 cubic feet are required.

Provision has also to be made for Combustion and its consequences. Air must be supplied in sufficient quantity to yield oxygen for fires and lights, and to dilute the gases resulting from combustion when these are permitted to escape into a room. 240 cubic feet of air should be allowed for the complete combustion of 1 lb. of *coal;* 120 for 1 lb. of dry *wood,* the carbonic acid and other gases produced escaping by the chimney. A cubic foot of *coal-gas* requires 8 cubic feet of air simply for combustion; therefore, about 25 should be allowed per hour for each burner, without taking into consideration the vitiation of the atmosphere of the room by the products of combustion, which latter should, if possible, be conducted immediately and separately to the open air.* As a cubic foot of coal-gas generates when burnt about two cubic feet of carbonic acid, an ordinary burner adds six cubic feet of this gas per hour to the atmosphere of the room, to compensate which 5,000 cubic feet of normal air must be supplied, unless the special outlets be provided. An ordinary *oil-lamp* generates about half a cubic foot of carbonic acid per hour, requiring 400 cubic feet of air for dilution. For a good *candle* 500 feet per hour should be allowed.

3. The Means of supplying the requisite amount of pure air may be divided into Natural and Artificial: the former including *perflation, aspiration* and *circulation;* the latter, *extraction* and *propulsion.* In tropical climates where the air is always warm the difficulty lies not so much in the supply of fresh air, as in the supply of *cool* fresh air; just as in other countries the air must be warmed. In the latter case the problem has been thoroughly and scientifically studied; as regards the former it is almost untouched.

Perflation is the blowing of a natural stream of pure air through a room or other space. General perflation by the passage of wind through doors and windows or

* By means of a tube with a funnel-shaped mouth placed directly over each gas jet, the other end of the tube opening into the outer air by passing through the wall of the room.

other openings is the most efficient means of ventilation and, in the present state of our knowledge, that which is, as a rule, best suited to this country and climate. A current of air moving at the rate of two miles per hour—a rate which does not produce a perceptible draught—through a doorway ten feet by four in area supplies 422,400 cubic feet of air per hour, a quantity sufficient for about 150 healthy men. A stronger wind will pass readily through a tent-wall, or through matting; and perflation takes place to some extent through single planks of wood and even through unplastered porous brick if the velocity of the current be high. Doors and windows should always be so arranged as to permit free perflation when the wind is only moderately strong.

It is desirable that the movement of the air blowing through a room should be nearly or almost imperceptible to sensation, so that there shall be no draught or chill. Air may be moving at a rate of a mile or even a mile and a half per hour while no movement is perceived. Imperceptibility of movement depends not only on velocity but upon temperature; and the higher the latter the more rapid may be the rate without inconvenience.* With the thermometer at 21° C. (70° F.) or upwards perflation at a considerable rate of velocity is attended by no sensation of chill. Even at lower temperatures than are ordinarily experienced in this country a velocity of a mile per hour is imperceptible, and a rate of a mile and a half is not disagreeable. It may be taken as a general rule that the rate of movement should not exceed 3·5 feet per second, *i.e.*, 2·4 miles per hour; and a lower rate will be objectionable if the air be moist or if it be of lower temperature than that it replaces.

There is another, but a less efficient and manageable, way in which perflation may be applied. Cowls turned

* Up to a certain point only. In the case of the extremely hot and dry *land winds* in this country a most disagreeable and even serious degree of exhaustion, accompanied by other unpleasant symptoms, may be produced.

towards the direction from which a wind is blowing may be placed at the top of a building, from which pipes of wood or metal convey the air received to rooms below. Direct communication between the cowls and the apartments to be ventilated is liable to be attended by draughts; but the streams of air can be conducted to the basement story of a house, there warmed or cooled as may be desired, and thence distributed by tubes to other parts of the building. Corresponding outlet pipes and openings, with cowls turned *from* the wind, will be provided for the issue of air commensurate with that blown in; and these by their aspirating effect will aid in ventilation. This second mode of perflation is applicable to the holds of ships, which the direct method cannot reach. A funnel of canvas, wood or metal receives the wind and a tube conducts it downwards. Distribution without draught is difficult here as in a house. The force of the in-blowing current may be reduced by having the conducting tube bent at right angles, once or oftener; or by interposing screens of perforated zinc in the passage; but ventilation is impeded in proportion as friction is increased by these expedients and the plates are liable to become clogged with dust and are with difficulty got at for cleaning. The stream of air admitted by this method may also be regulated by valves.

Aspiration is the drawing of air out of a room or building through a shaft by means of the wind blowing at right angles to the latter. In this way a small current of air moving with a high velocity over the upper end of a tube, provided with a cowl turned *from* the wind, influences a large body of air below, by producing an upward draught. This method withdraws air from a room and provision must be made for free admission of pure air in compensation. The stronger the wind the more copious will be the updraught and the more effective the aspiration, while a powerful blast cannot, as we have seen be borne in perflation. Neither method, of course, is applicable where the outer air is absolutely stagnant, and ventilation will then

depend upon either circulation or artificial means. It is also to be borne in mind that wind may impede ventilation by blowing across unprotected exit-openings, or down chimneys or other shafts.

The movement of air caused by differences of temperature is called CIRCULATION. Air heated by lights or fires or the bodies of men or other animals becomes lighter, rises and is replaced by colder air from above or from without, which is in turn warmed and similarly replaced. As this circulation depends upon the generation of a higher temperature within a room than that of the outer air and is active in proportion as the former exceeds the latter, ventilation by this means is chiefly applicable to cold climates and to rooms or buildings artificially warmed. In all inhabited rooms, however, it needs to be taken into consideration and due provision made for ingress and egress of air. In this country the external air is sometimes warmer than sometimes colder than and sometimes of equal temperature with the inside air, the result being that downward upward or no currents are formed, and in any case the current is never very strong owing to the fact that the difference in temperature between the external and internal air is never great. Still, when in very hot weather houses are closed in the early morning, the air within is, during a great part of the day, cooler than that outside; so that circulation is in this way also established and there is then no necessity for direct exposure of the body surface to the trying hot winds.

When this circulation is maintained, not by the ordinary sources of heat but by special contrivances, it forms one of the artificial methods of ventilation; namely, ventilation by EXTRACTION.* In an ordinary chimney, when a fire is burning below, an upward current of air, moving at a rate of from three to six feet per second, is produced; and if

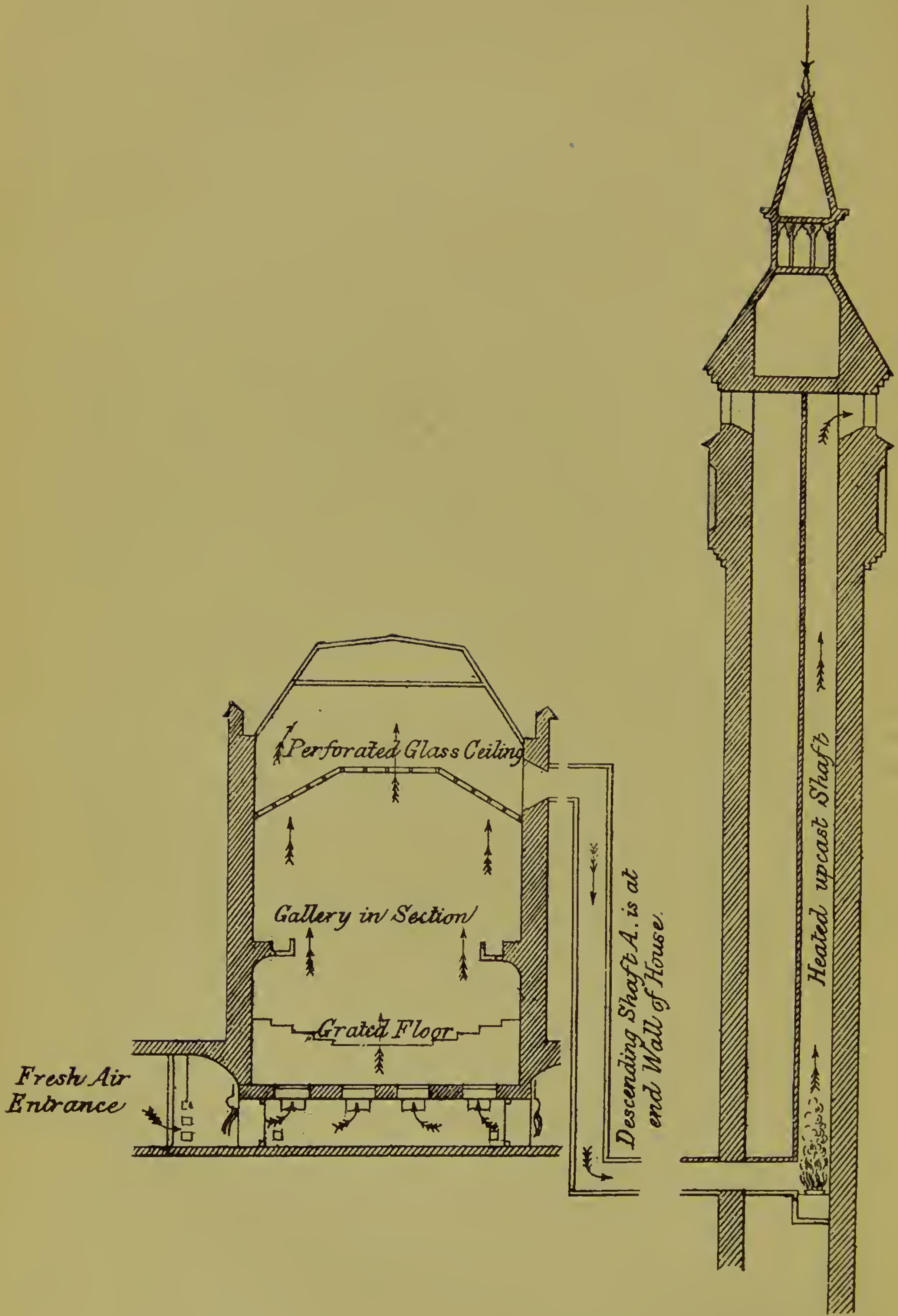
* The Vacuum Method.

the fire be very large a velocity of nine feet per second may be attained. Equilibrium will be restored by streams of air passing from other openings towards the fire-place, or, if there be no such openings, by a down-draught in the chimney itself, simultaneous with the up-draught. This principle is applied on the large scale to the ventilation of mines, where a large fire burning at the bottom of a shaft maintains a powerful upward current, while fresh air from the surface, descending through other openings, supplies the place of that withdrawn. In like manner large buildings are sometimes ventilated. A fire or a number of gas-burners or pipes filled with hot water heat the air at the lower part of a central shaft into which, owing to the strong upward current thus set up, the foul air from all the rooms is drawn, by means of special pipes opening into the shaft near its base. The fresh air is supplied to each room by windows or special inlets.

Several disadvantages attend this mode of ventilation, especially in the case of small buildings such as dwelling-houses. Heat supplied by a fire, which is the source most generally available, is not easily kept at a fixed temperature nor regulated to suit the varying circumstances of different rooms; if, from any cause, the requisite up-draught is not maintained from below, a down-draught will be generated in the shaft, which may bring with it into the building smoke or other products of combustion; and, under certain conditions, the air which is thus withdrawn may be replaced by air entering from any source, as for instance from sewers or through water-closets. Extraction by a screw-shaped Fan has been suggested and practised, especially in mills where a great deal of dust is thrown into the air: but the mechanical power which it requires can, as a rule, be more economically and efficiently applied to ventilation by propulsion.

Propulsion is the forcing in of pure air by mechanical means, either directly or through flues constructed for the

PLATE I.



LITH. BY ROSS, BROS.

To face p. 28.

PLATE I.

VENTILATION OF THE HOUSE OF COMMONS—LONDON.

(After Galton).—To illustrate ventilation by artificial means. Fresh air is supplied from the adjacent courtyards of the House by revolving fans which propel it along special conduits. On entering the basement it is filtered, washed, warmed or cooled, according to the season, and passed through four large circular openings (3′ 6″ diam. ea.) into the chamber under the floor, which latter is perforated to allow of the free passage of the air into the general body of the House. The vitiated air rises gradually and passes through the perforated glass ceiling into a space above, from whence it is drawn down an exhaust shaft opening into the basement at the foot of the clock-tower, where a large fire is kept burning in order to create a draught. The heated air then rises again and finally passes out through the heated upcast shaft. As much as 1,500,000 cubic feet have been passed through per hour, a quantity equivalent to 2,000 cubic feet per head per hour if the house was quite full, which it very rarely is for any length of time. The method above described is a combination of 'extraction' and 'propulsion'. [A simple modification of the above plan could easily be adapted for the ventilation of Indian hospitals, etc., the air being cooled before entrance, and an upward current created in the shaft by means of the sun or of a fire, according to circumstances (*v.* p. 227).]

purpose.* When labor is cheap and thorough ventilation by natural methods not attainable propulsion may be applied with great advantage. The quantity of air thrown in can readily be measured and regulated, and its temperature raised or lowered. The common thermantidote is a familiar instance of this method. It supplies a constant stream of pure air to a room or building, which may be passed through a moistened tatty and thereby cooled. The mechanism of the machine is simple and not easily deranged, and little labor is required for working it; but the distribution of the supply is generally faulty. Air enters at a high velocity and is liable to pass directly through a room in streams to the outlets instead of intermixing, thus producing draughts and inefficient ventilation.

Distribution can be more satisfactorily managed by the use of this method on the large scale. Large fans, worked by men or cattle or steam-power, force air drawn through a shaft, at least forty feet high and situated well away from all buildings, (to ensure purity of supply), into flues which communicate by branches and pipes with every part of the building to be ventilated. This plan is suitable for a jail† if the absence of wind for long periods renders natural ventilation insufficient, cheap labor being superabundant; but the first cost of machinery and buildings must be considerable. Its inventor suggests that canvas shafts may be substituted for masonry flues in applying this method to buildings; and also that portable

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* The Plenum Method.

† Mr. Stuart Clark introduced his "plenum method" into Agra Jail. One fan, 3½ feet in diameter, worked by hand at a speed of less than 300 revolutions per minute, was found sufficient to ventilate a corridor 283 feet in length with 68 cells opening from it. The machinery is placed to windward, about 300 feet from the middle of the line of buildings. An underground main-flue of masonry (4½ feet by 3) conveys the air to the jail. Smaller flues (2½ × 2 feet) pass under the floor of each block, and from these diffusion-pipes of earthenware, 9 inches in diameter, are distributed through the walls, communicating with the rooms by openings covered with perforated zinc. Besides the diffusion-pipes, "diffusion cases" are placed over the central flue and connected with it, 20 feet apart, in each building. With reference, however, to the foregoing, I am informed by the present superintendent that the method has fallen into disuse, "apparently because it did not prove a success."—[Ed.]

fans, etc., should accompany troops marching in the hot season, for the ventilation of tents.*

To ascertain whether sufficient provision has been made for the ventilation of any room the number of occupants and the volume of fresh air entering the room per hour, either by natural or artificial means, must be known. Dividing the latter quantity (after reductions for lights, fires, etc.,) expressed in cubic feet, by the former, the volume of pure air supplied for each person is obtained for comparison with the quantity stated above to be necessary.† The amount of air entering and escaping is determined by the anemometer, or, in the case of ventilation by circulation, by calculation.‡ The anemometer is an instrument which shows the velocity of a current of air in feet per second. The openings through which air enters having been ascertained by the deflection of a candle-flame, or by the direction taken by the smoke of smouldering brown paper, the rate of the entering current at each is determined. The rate per second multiplied by 3,600 gives the rate per hour; and this multiplied by the area of an opening in feet is the number of cubic feet per hour which that opening yields. The instrument should be placed as nearly as possible in the middle of the length of the passage and about two-fifths of the breadth from the side in order that the mean velocity may be given. It often happens that the outlet openings are less numerous

* The Punkah is a form of air propeller, but only to a limited extent. Opinions as to its efficacy differ considerably and exact experiments are wanting. The splendid steam-driven punkahs in the General Hospital, Madras, show this method of causing air-propulsion to its fullest extent. A punkah promotes intermixture and diffusion: when the temperature is lower than that of the body, it cools, by removing the layer of heated, ill-conducting and vapor-loaded air from the surface, substituting a colder film and favoring evaporation; when the temperature is higher it acts only in the latter way. Its use is favorable to comfort and to health, but not by promoting ventilation.

† This can be ascertained more directly by the chemical examination of the air coupled with the use of the formula (*b*) on p. 22.

‡ By the use of Montgolfier's formula (*v.* Parkes' Hygiene, 8th ed., p. 196), but ventilation by circulation is so imperfect in the tropics as a rule (*v.* p. 27) that this method of calculation is very rarely of any use.

than those of ingress of air, as, for instance, when a chimney discharges from a room a volume admitted by several inlets. It may then be more convenient to estimate the outgoing air, with which the supply will necessarily correspond. Casella's anemometer or air-meter will be found best adapted to the purpose.

The Relative Value of Natural and Artificial Ventilation is a question that must be decided by the special circumstances of any given case.* In very large buildings both methods may be available. In a cold climate like that of Great Britain, by far the larger number of houses are ventilated partly by perflation (when the weather permits) and partly by extraction, the chimney of each room being used as an exhaust shaft and the fresh air derived from any available source such as partially-opened windows, the chinks of the door, the entrance hall, etc. Such a method is usually exceedingly faulty, as any one who has occasion to enter an inhabited room on coming from the fresh outer air can testify. "In some circumstances however, as in the tropics, with a stagnant and warm air; and in temperate climates, in certain buildings where there are a great number of small rooms, or where sudden assemblages of people take place, mechanical ventilation must be used."†

In this country there is usually no difficulty in obtaining fresh air, and Europeans largely owe their health to the fact that they pass a great part of their time in what is practically the open air. But at times when the air is very stagnant and the difference between external and internal temperature almost *nil*, ventilation becomes most imperfect and the heat is proportionately trying. This is especially the case in large buildings such as town-halls, reception rooms, etc., which are liable to become suddenly crowded. Under such circumstances, if the air was first cooled and then driven through the house or other building

* As also in the case of Water-Supply and Disposal of Sewage.
† *v.* Parkes' Hygiene, 8th ed., p. 214.

by means of a fan, *e.g.*, the Blackman air-propeller, care being taken for its proper distribution, there is no doubt that great improvement in health would follow, sound sleep would be obtained and the climate would prove less trying.

CUBIC SPACE AND SUPERFICIAL AREA.

Having settled upon the amount of fresh air we are going to supply to any given room, we have next to consider the size of the room into which the air must be supplied, *i.e.*, the CUBIC SPACE. If 30,000 cubic feet of fresh air per head per hour have to be supplied to a room containing 10 men, it is obvious that if the cubic space of the room is 30,000 cubic feet the air in the room will have to be changed once in the hour; if it is 10,000 cubic feet the air must be changed three times, and if 3,000 cubic feet the air must be changed ten times and so on. If the air is changed too frequently draughts will be produced, and in a cold climate this is a very serious matter; for not only does serious illness frequently result, but the individuals for whose benefit the ventilation of the rooms is carried on frequently render abortive all such attempts by blocking up the chief places of entrance of fresh air. It has, accordingly, been found necessary to allot 1,000 cubic feet of space per head, and in this way 3,000 cubic feet of fresh air per head per hour can be supplied without the creation of a perceptible draught, the air of the room being changed only three times an hour. This of course is the amount that *should* be allowed, but in practice far less is given as a rule though public opinion is gradually being educated up to realise the importance of pure air. As we shall see later, in calculating the amount of cubic space certain deductions must be made for solid objects of furniture, etc., which diminish the cubic space, and it is necessary to remember also that the air is apt to stagnate in the corners of a room and thus the useful cubic space is still further diminished. Hence, it is easier to ventilate a large room than a small one.

In the tropics a somewhat smaller space might be allotted so far as the liability to the formation of draughts is concerned, but other considerations, such as frequent stagnation of the air, the heat absorbed by and afterwards radiated from buildings, etc., have to be taken into account so that instead of a smaller a somewhat larger space is necessary. Thus, it is ordered that in barrack-rooms in the plains 1,800 cubic feet should be allotted to each man; in hill-stations 1,200 to 1,400; in European hospitals 2,400 in the plains, 1,600 to 1,800 in the hills; in Native hospitals 1,500; in Jail-wards 648 cubic feet.*

In all cases there is a danger of overrating the importance of space allotment. *In an ill-ventilated room abundant space cannot postpone the consequence of deficient ventilation,* and the most careful obedience to rules providing against overcrowding should never supersede examination into the quantity of pure air entering and the quality of the atmosphere within.

But there is another matter which requires very careful consideration, and that is the amount of SUPERFICIAL AREA or 'floor-space' available for each occupant of a room. If the walls of a room are built very high the amount of cubic space may be large but the floor-space (*i e.,* the length of the room × the breadth) may be proportionately very small. Whenever possible, the floor-space should be at least one-twelfth of the cubic space and never less than 80 square feet per head. The considerations limiting the amount of cubic space and superficial area are chiefly those of expense and it is the duty of the Sanitarian to insist upon the importance of compliance with those standards as compared with the external or internal deco-

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* In the English Poor Law Regulations on this subject the minima are 850 cubic feet for ordinary patients, 1,200 for puerperal or offensive cases, 700 for the infirm and aged occupying the room day and night (otherwise 500), for healthy adults 300. The common lodging house allowance is 240 cubic and 30 superficial feet. The Educational Department allotment is 80 cubic feet per head as a minimum; much too little unless mechanical ventilation is used.

ration of a building. Horses and other cattle require about 1,500 cubic feet and 120 square feet more or less according as they are sick or in good health. It should be remembered that deficiency in cubic space is less likely to be hurtful than insufficient superficial area and should therefore be preferred when there is only a choice of evils.

Measurement of cubic space.—Measurements should be made in feet and tenths of a foot. If a measure so divided is not readily obtainable one inch should be disregarded, two inches are counted as 0·15, three as 0·25, four as 0·30, five as 0·40, six as 0·50, seven as 0·60, eight as 0·65, nine as 0·75, ten as 0·80, and eleven as 0·90. Square inches may be turned into square feet by multiplying by 0·007. In the case of an ordinary rectangular room the cubic space is found by multiplying together the length, breadth and height. In the case of irregularly-shaped rooms, tents, etc., the space to be measured must be divided into its component parts and the whole added together. By the use of the following table* the cubic space of any room, tent, etc., can be calculated whatever its space may be.

1. Area of circle	$= D^2 \times 0{\cdot}7854$.
2. Diameter of circle	$= C \div 3{\cdot}1416$.
3. Area of a square	= Length × breadth.
4. Area of rectangle	= Length × breadth.
5. Area of triangle	= Base × ½ height or height × ½ base.
6. Area of any figure bounded by right lines.	= Divide into triangles and take the sum of their areas.
7. Area of segment of circle.	= To ⅔ product of chord and height add the cube of the height ÷ twice the chord $\frac{2}{3}(Ch \times H) + \frac{H^3}{2Ch}$.

* Abridged from Parkes' Hygiene, 8th ed., p. 216.

8. Cubic capacity of a cubic or solid rectangle.	=	Multiply together the length, breadth & height.
9. Cubic capacity of a solid triangle.	=	Area of section (triangle) × the depth.
10. Cubic capacity of a cone or pyramid.	=	Area of base × $\frac{1}{3}$ height.
11. Cubic capacity of a dome.	=	Area of base × $\frac{2}{3}$ height.
12. Cubic capacity of a cylinder.	=	Area of base × height.

In this country the great majority of rooms are rectangular, the ceilings being flat; but where there is a ridged roof, as seen in many hospitals, etc., the cubic contents are found by dividing the room into a rectangle and a solid triangle and adding the cubic contents of these two together. Some forms of tent are merely solid triangles or cones, whilst others are more complicated; but, as stated above, the cubic contents of any confined space can be calculated from the foregoing table.

Having thus determined the capacity of a room or other space in cubic feet, with recesses or other additions not included in the general measurement, deductions are to be made for the bulkier articles of furniture and for the bodies of occupants. Large presses, chests of drawers, etc., will be measured. In hospitals, barrack-rooms and bedrooms 10 cubic feet are allowed for each set of bedding; and in all cases 3 cubic feet for each person.*

INLETS AND OUTLETS—THEIR POSITION, NUMBER, SIZE AND FORM.

The openings with which ventilation is concerned are divisible into two groups; those of Inlet or Adduction

* Women and children do not require so much fresh air nor so much cubic space as adult males; but abundance of pure air is so important that in the text and elsewhere no reduction is suggested on this account.

through which pure air enters and those of Outlet or Abduction for the escape of vitiated air. The direction and force of the air currents and, therefore, the proper distribution of the supply depend upon the management of the openings and the mutual relations of the two classes. In warm climates it often happens that doors and windows supply all necessary ventilation without producing draughts or chill and in some cases pervious walls, as of mats or bamboo, allow of free perflation without disadvantage.* In colder climates doors and windows must generally be closed, and special openings provided for inlet, and for outlet also if the chimney is not sufficient. In the colder parts of this country portions of walls of rooms may be formed of tiles so as to be freely pervious during the hot months, but requiring to be closed (as with movable wooden coverings) during the cold season, when other openings will be necessary for ventilation. The consideration of such special apertures, therefore, as well as of the ordinary openings of a room, tent or building is of great importance

* We have usually in India to depend upon the wind for natural ventilation, and it is manifest that unless revolving cowls or artificial ventilation be resorted to, the same openings must serve somtimes for ingress and sometimes for egress of air. The most simple and direct methods of ventilation are therefore the best; and tubes, shafts, and valves, should, as a rule, be dispensed with. In single-storied buildings, with low roofs, ridge-ventilation may be all that is required. In higher buildings ventilators may be placed in doors or windows at a height of six or seven feet, or separate ventilators may be placed in the walls. Direct ventilation at the ground level through the walls is generally to be deprecated, as foul air is more likely to be found near the ground than higher. In the huts of the poor, and even in the houses of the wealthy, there is often an insufficiency of windows for good ventilation, even when they are open. Where this is found to be the case ventilators can, as a rule, be inserted at a very small cost. Tiled roofs, even where no ridge ventilation is provided, generally afford a pretty free passage to air. When, as occasionally happens, the wind fails entirely, and there is no difference of temperature outside and in, to cause any movement of air, natural ventilation is impossible, and the air can be but slowly purified by the diffusion of gaseons and the subsidence of suspended impurities. In such circumstances, doors and windows should be fully opened and people should, if possible, remain in the open air. The creation of movement by artificial means, as fans and punkahs, is particularly valuable under such circumstances. Ventilation by shafts with revolving or fixed tops of various kinds, is only efficient as long as the wind is pretty strong, that is, when they are least wanted; but when the wind fails they cease to act as intended, and are less useful than ordinary fixed openings. Such contrivances are therefore, as a rule, to be avoided for house ventilation.—*McNally.*

in ventilation. They may be examined with reference to Position, Number, Size and Form.

Inlet openings are to be selected or made in such Positions that the entering air may not be polluted before admission, as by marsh exhalations, sewer effluvia, emanations from latrines or water-closets, discharge from outlets of other rooms or buildings, etc.; secondly, equable distribution and thorough intermixture of the pure supply are essential. Hence, where perflation is possible, there should be doors and windows in opposite sides of the room. In other cases special inlets should be provided near the floor, unless when the supply is so cold that it cannot be borne with comfort and means of heating it artificially before entrance are not available; then it may be admitted at about ten feet from the floor and directed upwards so that falling subsequently by its greater weight it may be equally diffused through the atmosphere of the room. In our climate the floor openings will generally be found suitable.* Respired air first rises; therefore outlet openings are provided at the upper part of the room, tent, etc. In single-storey buildings with sloping roofs, as most of our hospitals, no arrangement can be better for discharge of vitiated air than properly protected ridge-openings along the entire top. As a general rule the highest outlet is that from which discharge is most rapid; but the application of artificial heat, whether specially for favouring egress of air or for other purposes, powerfully affects the rate of discharge through and position of outlets. Thus the chimney of a room in which a fire is burning is always the principal and often the sole channel of discharge; and heating an outlet-tube with gas, whatever its position, increases its effectiveness. Finally, the *relative* positions of inlets and outlets must be considered. It should not be possible for fresh air to escape, without intermixture, through an outlet placed too near the aperture by which it

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* *v.* however, note on previous page.

entered, and, generally, the opening should be so arranged that the movement of air in the room will be vertical, not horizontal; so that air vitiated by one person's respiration (or, in hospitals, by one patient's exhalations) should not pass across the position of another.

The Number of inlet apertures will be determined by the necessity for equable distribution of the fresh air, so that whether they be the ordinary openings of the room, or specially provided for ventilation, they should be (if correspondent in size) at equal distances from each other. In hospital wards, barrack-rooms, etc., for each bed there should be an inlet aperture. Provided the number of inlets is sufficient for proper distribution, that of outlets is unimportant. An ordinary chimney, when a fire is burning, will give sufficient discharge for a room in which four or five persons breathe; and one large outlet, in other cases also, will suffice for a building which requires many inlets.

The Size of special ventilatory openings will vary with the number of occupants of the room, the degree in which ventilation is dependent upon such apertures and the difference between internal and external temperatures, on which rapidity of circulation depends. In the tropics, as explained before,* where ventilation by circulation is frequently very imperfect and where the changes in temperature when they do occur are apt to be very marked, it is impossible to apply the results of any given formula satisfactorily so as to have a system of inlets and outlets suitable for all occasions. In the colder parts of this country where the difference between the external and internal temperature may be 10° F. or more, it is useful to have a series of inlets and outlets which can be closed or opened at will, so that when ventilation by perflation is impossible and the doors and windows are closed, ventilation by circulation can be brought into play. Where

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* *v.* Note ‡ p. 30.

fires are used the only outlet necessary, save in large barrack rooms, etc., will be the chimney. The outflowing air being warmer and therefore bulkier than the incoming, the apertures of exit should, theoretically, be somewhat larger than those of entrance and the proportion is sometimes given as 11 : 10, but in practice this is a point of no importance. As regards absolute size of the two classes of apertures it is laid down that the distribution of the entering air is most successful when each inlet does not exceed 48 to 60 square inches (the allowance for two or three persons), and each outlet is not more than a square foot in size (or sufficient for six persons).* When a building is to be ventilated by one of the various systems of artificial ventilation the nature, size and arrangement of the inlets and outlets should be settled by skilled sanitary experts, as they vary very much according to the system adopted.

Lastly, the Form and management of ventilatory openings have to be considered. In the case of *perflation*, if the wind have a high velocity, means must be adopted for efficient distribution without the production of draughts. Windows should open at the top, or sloping from below upwards and inwards, so that the cooler entering air may be directed towards the roof or ceiling to sink equably by its superior weight. Or a window may be divided into sections each opening separately with such an upward

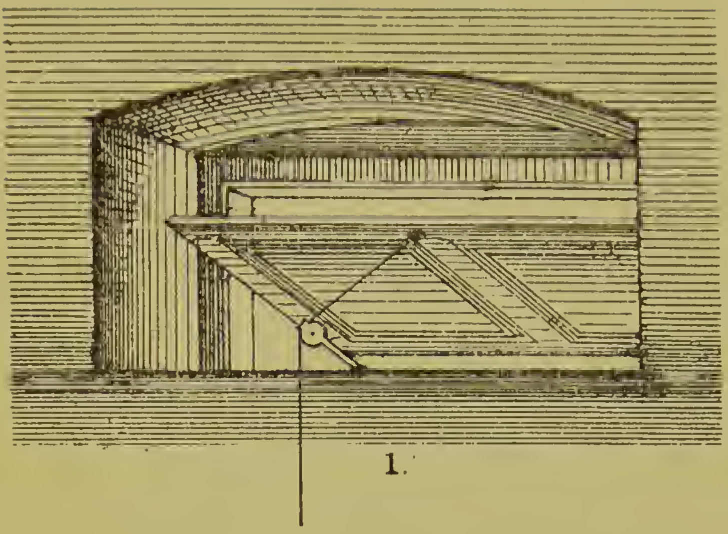
* The Barrack Commissioners allow 11 square inches of outlet aperture for each healthy person occupying a room, *i.e.*, nearly a square foot for 12 men, in addition to the chimney. This may be taken as from 20 to 24 square inches per head for inlet and outlet, and the space should be doubled in hospitals. In Netley Hospital the total inlet area in nine-patient wards (besides doors and windows) is 162 square inches, or 18 square inches per man; in fourteen-patient wards, 15½ square inches per man. The outlets are 17 and 16 square inches respectively. There is great difference of opinion among hygienists in this matter of inlet and outlet areas, probably due partly to variations in the difference of temperatures and partly to estimating with reference to cubic space. One authority lays down that a square inch of inlet should be allowed for 120 cubic feet, or 60 square inches for a room occupied by 12 men with 600 cubic feet per head. As to outlet Parkes recommended 1 square inch of inlet for 60 cubic feet and for outlet 1 inch for 60 cubic feet on the ground floor, for 55 on first floors and 50 on second or for a one-storeyed building.

slope. In windows opening in the ordinary English way, *i.e.*, with the sash moving vertically, the requisite direction may be given to the stream of air by a sloping board. Some panes of the glazing may be double, with openings below in the outer and above in the inner glass; or one or more panes may be fitted with glass louvres. Some may be of wire gauze or perforated zinc instead of glass; or moveable frames with one of these materials may replace the sash when raised or thrown open. In India the windows nearly always open outwards or inwards instead of upwards and in such a case it is not easy to regulate the direct force of the wind. In the day-time the outer wooden venetians may be kept partially closed whilst the inner glass windows are open and thus excess of sun-light and wind be prevented from entering. When *aspirating* tubes and shafts are used the upper ends should be protected from the entrance both of rain and of wind, while their special action is favoured by widening the aperture so that its size exceeds considerably that of the passage itself. This expansion or cowl revolves, so that the opening is always turned from the direction of the wind, and its upper rim projects a little so as to exclude rain from the shaft. Louvred terminations to aspiration shafts are apt to admit rain and also down-draughts, and aspiration is not so powerful as when a revolving cowl is employed. It is a good arrangement to make the shaft terminate in a revolving cylinder open at one side and moved by a vane so that its aperture shall always be away from the wind, the whole being protected by a fixed louvred covering.*

Where ventilation is dependent upon *circulation* inlet passages should be short so as to admit of being readily cleaned, as dirt lodging in them may communicate impurity to the entering air; externally the openings should be pro-

* For detailed description of the numerous forms of shafts, cowls, etc., in use in temperate climates, *v.* the works of Buchan, Eassie, Stevenson and Murphy, etc. There are still many points unsettled and a 'perfect' cowl is a thing of the future. The latest investigations seem to indicate that a revolving cowl does *not* increase the aspirating power of the wind.

PLATE II.



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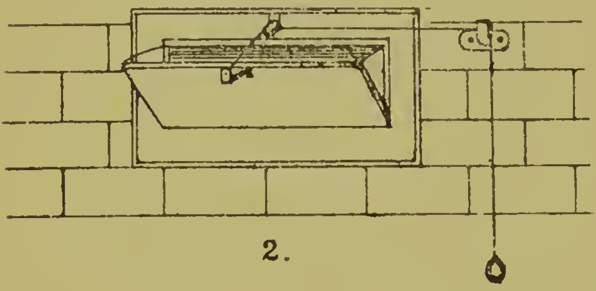

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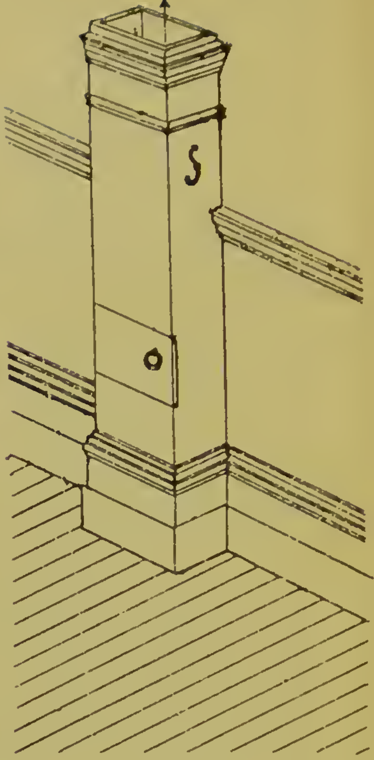

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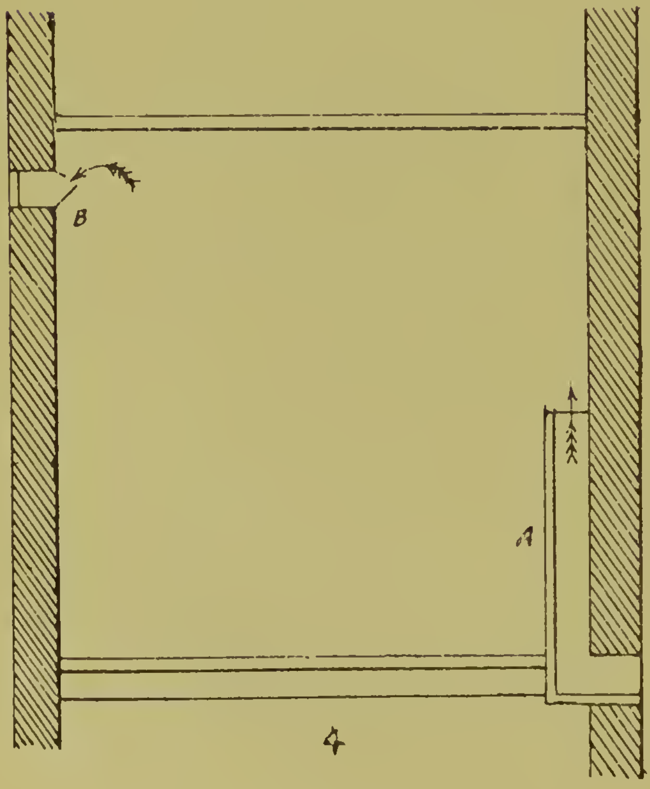

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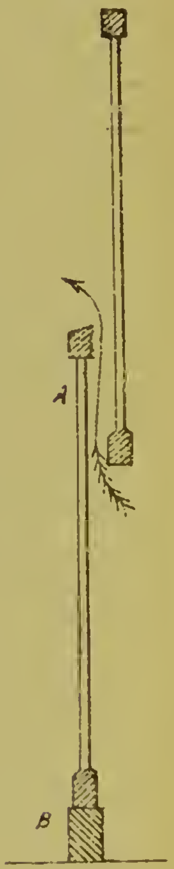

5.

LITH: BY ROSS, BROS.

To face p. 40.

PLATE II.

VENTILATORS.

Figure 1. Form of Ventilator commonly used in India and placed above doors or windows to form a Clerestorey. It may act as inlet or outlet, or both, according to circumstances. It may be opened or closed at will.

Figure 2. The Sherringham Valve. Externally it consists of a perforated brick or iron box placed in the wall, through which the air enters and is directed upwards by the valve. It sometimes acts as an outlet (*v.* fig. 4). Its chief advantage is that it prevents the wind blowing in directly and causing a perceptible draught. It can be opened or closed at will, and can be easily cleaned. (Usual size of inlet opening is 9″ × 3″ = 27″ square, the external opening being slightly smaller).

Figure 3. Tobin's Tube. The air enters from without through a perforated brick or iron plate at the floor level and passes up the tube. At a height of about 8 feet (3 or 4 feet above the top of the tube) it spreads out and mixes with the air of the room. In time, the tube is apt to become a receptacle for dust, insects, etc., and thus to render impure the incoming air. In addition, owing to its length, there is considerable friction, with a resulting diminished velocity of the air current.

Figure 4. Diagram of a Room Ventilated by Means of a Tobin's Tube (inlet), A., and Sherringham Valve (outlet), B.

Figure 5. Hinckes-Bird's Ventilator (seen in section). B. Block of wood placed under the lower sash frame, A., of the window, whereby the top of the lower sash is raised above the bottom rail of the upper sash, and an air-space left between, through which air enters in an upward direction. This method is only available for windows opening vertically, the use of which in India is chiefly confined to certain Hill stations.

it is recommended that outlet shafts should rise some distance above the roof, the upper portion built of brick and blackened. Finally, it is to be borne in mind that an outlet may, under certain circumstances, become an inlet; and provision must be made for the proper distribution of the entering air, should this occur.

EXAMINATION OF THE VENTILATION OF A ROOM OR BUILDING.

1. For this to be done thoroughly the building and its precincts must first be carefully inspected with a view to the discovery of any nuisance in the shape of accumulations of rubbish, foul drains or latrines, stagnant water, etc., etc.*

2. The cubic space and superficial area of the various rooms must be estimated in the manner described above and the ordinary number of occupants of each room ascertained.

3. The number, size and relative position of the inlets and outlets must be noted and whether the inlets will act as outlets under changing atmospheric conditions and *vice versâ*. The actual amount of air entering or leaving the room, preferably the latter, is estimated by Casella's air-meter, or, under suitable conditions, by calculation. The most important point to attend to, besides the actual amount of fresh air entering, is whether the distribution of the air is equable and thorough. In many cases it will be found, by the use of a smouldering piece of rag or some strong-scented substance, that the air passes almost directly from an inlet to an outlet. A lighted candle held close to an orifice will show whether air is entering or passing out, even when the current is extremely slow.

4. A specimen of the air of the room taken during occupation of the room, *e.g.*, in the case of bed rooms about 3-4 A.M., should be examined as completely as possible by approved chemical, microscopical and biological tests.

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* *v.* under Buildings.

5. If this (4) cannot be done, two rough and ready tests may be employed. *a.* Smell test. The examiner coming straight from the outer air should enter the room at a selected time of occupation and note whether there is any perceptible odor or not. If there is none the ventilation is probably satisfactory. If there is any smell he should note whether the atmosphere is "close," "close and unpleasant" or "very close and foul." A little practice enables very considerable accuracy to be obtained by this test. *b.* Lime water test. A clean dry eight-ounce bottle is filled with the air of the room by pumping into it with a small pair of bellows, and three and a half drachms of freshly-made and clear lime water is added. The bottle is then thoroughly shaken and put aside for six hours. At the end of that time the lime water should still remain clear; if found turbid it indicates that a total of more than 0·7 volumes CO_2 per 1,000, (*i.e.*, 0·1 volume CO_2 per 1,000 in excess of admissible respiratory impurity) was present in the air.

6. Finally, the amount of air supplied and utilised (as ascertained by chemical examination) should be compared with the amount indicated by the air-meter. If the distribution of the air is equable there should not be much difference in the two estimations. If the amount registered by the air-meter is in excess the distribution is bad, if it is relatively deficient then some inlet has escaped notice.

CHAPTER II.

WATER.

The provision of a sufficient and suitable water supply is of supreme importance in the tropics.. The very existence of the population may be said to depend upon it, for famine in India is almost always the direct result of a deficient supply and consequent failure of the crops. Next in importance to the *sufficiency* of supply comes the question of *purity* of supply. An enormous proportion of the mortality and of chronic disease in this country is due to the fact that the use of impure water is the rule and not the exception. Hence for many centuries great and wise rulers wishing to perpetuate the memory of beloved friends and at the same time to confer lasting benefit upon their subjects have caused to be executed works for the collection and storage of water, in some cases for the purposes of irrigation and in others for the supply of good drinking water. The subject can only be treated of here in a very condensed form, but it is evident that it is steadily claiming greater attention from those in authority and from the educated classes of the Indian community, and while Irrigation works on a very large scale are being carried out on the one hand,* on the other the supply of pure water for household purposes to all towns, and ultimately, let us hope, to all villages, is being pushed forward. That the annual waste of water during the rainy season is enormous is evident to the most casual observer, and the consideration of the methods by which the surplus water may be conserved and utilised, as far as practicable,

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* *E.g.*, the so-called Periyar Project in Southern India, by which, when completed, a large portion of the excess of the rainfall that naturally runs seaward down the western side of the ghâts, will be dammed up and caused to run down the drier eastern slopes so as to irrigate the adjacent country.

is well worthy the continued attention of Meteorologists, Engineers and Sanitarians alike.

The subject falls to be considered under the following heads: 1. The Source of the supply, including the Search for water. 2. The Mode of Supply and Estimation of Supply Available. 3. The Storage of water. 4. The Distribution of water and the Amount Required for various purposes. 5. Drinking water, its Nature and Impurities. 6. Diseases resulting from an Impure supply. 7. The Purification and Filtration of water. 8. The Examination of water.

SOURCE OF THE SUPPLY AND THE SEARCH FOR WATER.

Whatever be the nature of the water supply in any particular place it is primarily derived from the rainfall.* Some of the water that falls as rain is evaporated, some of it flows over the surface of the ground and goes to swell already existing lakes and streams, whilst the remainder gradually sinks through the interstices of the soil till it is stopped and, it may be, partly absorbed, by a so-called impermeable stratum of rock or clay. The water which has thus filtered down to the deeper strata is known as the Ground-water† and forms a most important source of supply by means of natural springs, or wells made artificially. The exact proportion of the rainfall which is evaporated, flows away or sinks into the neighbouring soil depends on many factors varying with the season and the locality,‡ but it may be roughly estimated at one-third in each case. The remote source of any water supply is therefore the rainfall, whilst the immediate source is one of the following:—

1. Rain water itself collected as it falls. 2. Lakes or

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* In some cases as frozen rain or snow. The snow-clad mountain ranges of India and Thibet form immense natural reservoirs which yearly, at the time of melting of the snows, send down vast quantities of water to the parched plains below, by the great rivers that take their rise in these distant valleys.

† *v.* under Soil. Chapter III. ‡ *ibid.*

Tanks, which may be natural depressions in the earths surface, or artificially constructed by damming up the mouth of a narrow valley. Sometimes a small lake exists already and by deepening its bed and erecting a *band* its size may be very much increased. In India many of the tanks are altogether artificial and consist of an oblong or circular area completely *banded* round, and which is chiefly fed by the direct rainfall. 3. Wells—Shallow, Deep or Artesian. There is no fixed limit of division between a shallow and a deep well but the former is generally defined as a well which is of any depth up to 50 feet, the latter as about 100 feet in depth or more. Practically, any well which does not pass through an impermeable stratum is a shallow well. Artesian wells are made by boring, generally to a great depth, through various strata until a water-bearing stratum lying underneath an upper impermeable stratum is reached. They may be regarded as a variety of deep well or again as artificial springs. The water in the deep permeable stratum is frequently under considerable pressure so that it may be discharged in the form of a fountain or jet from the orifice of the well. 4. Springs. 5. Rivers and rarely Canals. 6. Distillation, chiefly of sea water.

The Search for Water.—The indications of the presence of water and the SEARCH for it may not improbably be points of great importance to exploring or survey parties, to troops marching in an unknown country or to officers selecting a site for a camp or a station. In the first place, wells should be sunk in permeable strata only, unless geological examination of the country has shown that impermeable rocks overlie permeable, and that the latter crop out, so as to receive the rainfall or water from other sources. On this principle, on the large scale, artesian wells are sunk to enormous depths through impermeable rocks into underlying permeable and water-bearing strata. Secondly, rivers apparently dry flow subterraneously and water will almost always be found by digging in their beds. Similarly,

the dry courses of nullahs are promising sites for wells, and more especially at the point where two unite. Thirdly, greater abundance or verdure of vegetation often indicates closer proximity of water to the surface : and where there is no vegetation, as on a sandy plain, fogs in the early morning give reason to expect water at no great distance below. Fourthly, amongst hills the lowest convenient part of a valley should be chosen, and a spot which is nearer to the higher bounding hill : and the junction of two valleys will be preferred. Fifthly, if there is any indication of an extensive geological 'fault' in the neighbourhood, the probable presence of springs along the line of faulting must not be forgotten. Lastly, on the coast, the immediate neighbourhood of the sea should be avoided, unless an impermeable barrier of clay or rock prevent the percolation of salt water. In some parts of India as at Berhampore in Ganjam and Madras, etc., most of the wells yield brackish water unfit for drinking, whilst close by a well may be found to yield perfectly sweet water.* Norton's tube-wells are sometimes of great use if the soil is not too sandy. They consist of lengths of iron tubing which are driven into the ground, section by section, the first section being pointed and perforated with small holes. If the pressure of the water is insufficient to cause it to rise to the surface an ordinary pump will do so effectually up to 25 feet; beyond that depth it is necessary to use a special force pump.

METHOD OF SUPPLY AND ESTIMATION OF SUPPLY AVAILABLE.

In the case of small Indian towns and villages the method of supply is commonly the DIRECT one, *i.e.*, the water for domestic use is drawn by hand from wells or tanks, or sometimes from a river. Such water is usually highly

* Due to the existence of strata containing much chloride of sodium, the irregularity in the distribution of salt and sweet water being caused by irregular and impermeable beds of clay. The water of the Seven Wells at Madras is filtered naturally through a bed of fine sand 300 or 400 yards in breadth and from 1 to 15 feet deep, which extends northwards for several miles, and water drawn from below this bed is brackish.

impure and to its continued use may be traced a large portion of the annual mortality in India. In the larger towns also this custom still obtains but of late years a good many towns have adopted the much more satisfactory INDIRECT method, where there is one common regular source of supply, generally situated at some distance from the town, and from which the water is conveyed, after purification, by open or closed channels, to a suitable spot for distribution throughout the town. Before any such scheme can be adopted there are very many important questions to be settled, *e.g.*, cost of the work, permanence of the supply, etc., which questions however do not fall to be considered by the Sanitarian. The work of the latter relates entirely to the purity or the reverse of the proposed supply and before this can be settled the ground-surface whereon the rain falls, the so-called 'catchment area,' must be most carefully examined, all possible sources of contamination of the water supply at any point must be investigated and of course a careful analysis of the water itself must be made to see that it is free from hurtful impurities both organic and inorganic.

Estimation of Supply.—It is of great importance to know the probable amount of water which will be available for use under any known method of supply. This is chiefly a question for engineers, but a medical officer may have to calculate it roughly in the absence of skilled assistance.

1. Rainfall. In estimating the annual yield of water from rainfall, or the yield at any one time, it is necessary to know: (*a*) the greatest; (*b*) the least; and (*c*) the average annual rainfall; (*d*) the period of the year when it falls; and (*e*) the length of the rainless season. The greatest is generally about one-third more, and the least one-third less than the average. A safe basis is to take the average of the three driest years; this will generally be about five-sixths of the average annual rainfall. The rainfall varies in amount often in places very near

together. The amount of water given by rain is calculated from the amount of the rainfall and the area of the receiving surface. The former is ascertained by a rain-gauge. The area must be measured in square feet and the total multiplied by 144 to bring it to square inches. This multiplied by the rainfall (in inches) gives the total amount, in cubic inches, of the fall on the measured area in a given time. This multiplied by the short factor 0·003607 gives the number of gallons. One inch of rainfall is = 4·673 gallons on every square yard, *i.e.*, 22,617 gallons (101 tons by weight) on each square acre.

2. Wells. The yield of wells is liable to vary greatly in different years. In the case of shallow wells this variation depends upon the rainfall directly: in deep wells, many causes, which cannot be detailed here, combine to produce a varying yield. The water supply from any well may be measured by making a mark at the then level of the water and pumping or baleing out water till the level is some feet lower; then measuring the space from which the water has been removed and noting the time that it takes to fill again. The cubic contents of the space are found by multiplying the *cross area* of the well by the depth of water removed. Ex. A circular well 5 feet in diameter, from which 3 vertical feet of water had been pumped out, took 6 hours for the water to reach its former level. Then, the cross area* is $5^2 \times 0·7854 = 19·6$ square feet. $19·6 \times 3 = 58·8$ cubic feet the cubic contents of the space. Now 1 cubic foot of water is = 6·24 gallons, and since the space took 6 hours to fill, the total yield in 6 hours was ($58·8 \times 6·24 =$) 366 gallons (nearly); *i.e.*, in 24 hours the total yield would be ($6 : 24 :: 366 : x$) = 1464 gallons. If a cask be used for measurement, its contents in gallons may be estimated as $= 26\ (h^2.\ 25 + b^2.\ 39 + bh.\ 26) \times 0·000031473l$: where h = least and b = greatest width, and l = length, in *inches*. Should the only available measure be a part of a cask or a tub, the contents in gallons

* *v.* p. 34.

of each 10 inches are the quotient of the square of the mean diameter of those 10 inches by 3530·4. The mean diameter of the lowest 10 inches (for example) will be half the sum of the diameters at 5 and at 15 inches from the bottom. These methods are only approximative but rigid accuracy is obviously unnecessary in the case.

3. Springs. From the time which is required for filling a vessel of known capacity from a spring its yield is calculated. The yield of a spring or of a small stream often varies at different hours of the day; and determinations should, therefore, be made at several different times.

4. Streams and Small Rivers. The yield may be calculated in the following manner. Choose or make a straight length of as many feet as possible in the course of the stream. If the breadth and depth of this part of the channel are not uniform, measure them in several different places and take the mean of the products for the sectional area (a). Mark with two stones a distance of 150 to 200 feet at least, and note the time which a piece of wood about 4 inches square and $\frac{3}{4}$ inch thick, put into the middle of the stream above the upper mark, takes to reach the lower one. This observation gives the surface velocity; and this, multiplied by 0·8 (for small streams, 0·9 for rivers), is the mean velocity (V). Then $D = a\ V$, D being the discharge of water sought.* It may be more convenient to calculate by means of a Sluice-gate through which the stream is made to pass. Here $D = a\ 5\ \sqrt{h}$; a being the area of the opening through which the water passes, and h the height of the water level above the sluice from the centre of the aperture. Or again, the whole stream, if a small one, may be dammed up and directed into a wooden trough or channel of known dimensions. Then, by measuring the depth of

* For example, let surface velocity be 50 feet per minute $V = 50 \times 0·8 = 40$ feet per minute. Let mean depth be 1·5 foot, mean breadth 2 feet; mean sectional area = 3 feet. $D = 40 \times 3 = 120$ cubic feet per minute, which, multiplied by 6·23 = 747·6 gallons per minute.

water and noting the time a small float takes to travel from one end to the other, the necessary calculation can easily be made.

STORAGE OF WATER.

In any case where the indirect method of supply is determined upon it becomes necessary to arrange for the STORAGE of a fixed amount of water so that there may be no chance of its running short by reason of drought or a suddenly increased demand. In addition, the water has in nearly every case to be more or less purified by artificial measures before it is fit for distribution. Supposing then that the supply for any given town is from one or more tanks connected together by open channels, the tanks being filled by the rainfall over a chosen gathering ground or 'catchment area' or from a river at some fixed point situated well above the town; or from a series of natural springs or deep wells at the base of a range of hills; the first thing to be considered is what amount of water must be kept stored ready for use. In the first two cases it would only be necessary to build comparatively small storage reservoirs holding sufficient purified water for a month's supply or so, but where there is only one large artificial or semi-artificial reservoir it is essential to store a supply for a much longer period. "The dimensions of the reservoir must depend upon the distribution of the rainfall, and it may be laid down as a rule, that they should be calculated more with reference to the maximum demand and the minimum supply than to the average of either. A capacity of storage equal to about six months consumption, in addition to the quantity which is likely to be evaporated, appears to be the least which should be admitted when it is proposed to supply any agglomerated population in this manner."* Hawksley's formula for storage is as follows:—$D = \frac{1000}{\sqrt{F}}$, where F equals the mean annual rainfall in inches, say $\frac{5}{6}$ of average annual yield; D is the number of days' supply to be stored.

* Law—Clark. Civil Engineering, 7th ed., p. 82.

Thus, with a rainfall of 36 inches, we have $\frac{1000}{\sqrt{36}} = 166$ days' supply.*

Large reservoirs are made by excavation or embanking. The *band* should have a core of clay puddle and be faced internally with stone set in hydraulic mortar. Evaporation at a given temperature being proportional to extent of surface, the latter should be as small and the depth as great as possible.† Before entering the reservoir the water is made to pass, generally, through a rough filter consisting of a 'grating' or a 'submerged sluice' which stops all floating matter, a 'catchpit' or a small 'settling reservoir' in which the heavier suspended matters sink to the bottom, and finally through several layers of graduated gravel and sand, the water passing upwards ('upward filtration'). In addition, an overflow pipe or 'waste weir' and 'scouring' or 'cleansing pits' are provided so that the amount and nature of the water entering can be regulated and the whole reservoir be emptied and cleaned if necessary. Finally, the reservoir may be covered in or left open. In the former case the increase in the cost is very great, and it is rarely necessary.

Water thus stored in large reservoirs is very apt, like all water which is stagnant, or nearly so, to deteriorate by the growth and decay of low forms of animal and vegetable life and great trouble must be taken to prevent this. Certain plants such as *Vallisneria* and *Chara* seem to act beneficially by giving out a large amount of oxygen: the presence of fish and molluscs in limited amount is also desirable.‡ Sometimes the water is aërated artificially before distribution by exposing it for several hours to the atmosphere in fine jets.

In thinly-populated districts or isolated houses smaller

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* *v.* Parkes—Notter. Hygiene, 5th ed., p. 38.

† Loss by evaporation has been known in Calcutta to amount to as much as 2·5 ins. in 24 hours.

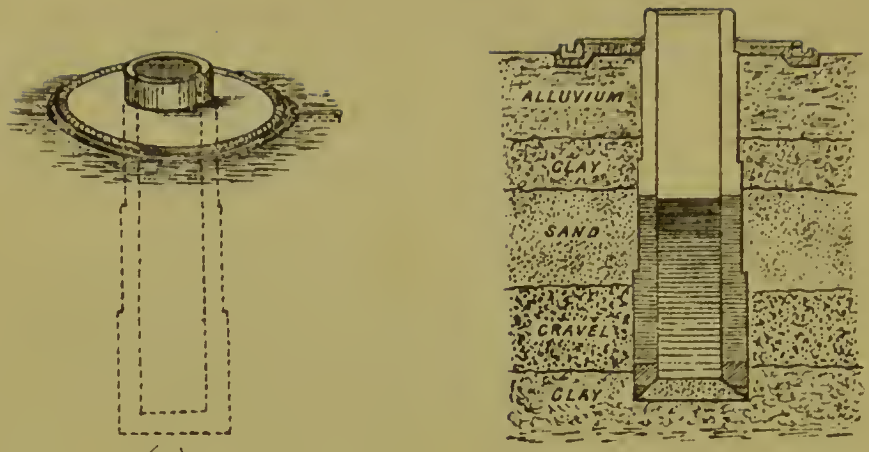
‡ *v.* Chevers—Indian Diseases, p. 136.

reservoirs made of stone or cement are used, but the principle is the same. In places where the annual rainfall is low, and consequently water is scarce, subterranean *reservoirs* may with great advantage be constructed for the storage of rain water falling on the roofs of large buildings. Such receptacles should be built of stone or well-burnt brick, set in hydraulic mortar and lined with portland or other suitable cement; they should be dark, but well-ventilated, deep rather than wide and capacious in proportion to the maximum rainfall. There should be no possibility of pollution by percolation from drain, sewer or cess-pool. The rain should not enter directly from the roof, but should be received in a shallow, carefully lined well, having two or three feet of sand and gravel through which the water passes on its way to the reservoir; and a second filtration by ascent may beneficially be interposed before the latter is reached. The filtering-well should be covered in; and the filters renewed before the setting in of each rainy season. Finally, whenever a reservoir becomes empty, it should be thoroughly cleansed.

Cisterns are used with great advantage for storing smaller quantities of water for domestic use. These are made of stone, brick faced with cement, slate, wood lined with glass, tiles, lead, zinc or iron. Slate is very good; lead is dangerous under all circumstances; zinc frequently so on account of the lead it contains. Cisterns should be emptied periodically and carefully cleansed; they should be covered in, and the pipe which conveys away overflowing water from them should never pass into a sewer or closed drain (lest offensive gases should ascend and be absorbed by the water); but it should terminate either in an open surface drain or at some distance above the opening of a covered passage. As to the *sufficiency* and *strength* of a tank or other reservoir, its capacity in cubic feet, multiplied by 6·23, gives its contents in gallons; and the weight of a cubic foot of water, and, therefore, its pressure on a square foot of surface, may be taken as 62 lbs.

When wells are used, as is so commonly the case in India, great care should be exercised to preserve the water from contamination. That portion of the rain which sinks into the ground percolates into wells, dissolving the soluble matters with which it meets in its course, aided, as we shall see, by carbonic acid derived from the soil. The space thus drained by any well, and consequently the supply of impurities on which it draws, varies with its depth and the nature of the soil. Thus if the soil is very loose a well of 80 to 100 feet in depth may drain a cone whose apex is at the bottom of the well, and whose base is a circle of 50 feet radius. A well may be considered secure from pollution situated external to a cone of half a mile radius, whatever be its depth or the looseness of its soil; but it is not possible to lay down precise rules on this point. Sea-water will penetrate through considerable distances unless impermeable clay or rock protect the well. Cess-pools, sewers, pools of stagnant water may contaminate wells with organic matters in solution and even in suspension, if situated within the drainage-cone. So also excrementitious and other refuse substances lying on the surface of the ground will contribute organic impurities to the soil and thence to the well water. It is true that the soil at first acts powerfully as a filter, intercepting most of the suspended impurities and those most likely to be injurious to health; but the purifying effect necessarily diminishes in time, and may even be reversed when the soil becomes saturated with filth carried in from the surface by percolating water. Besides the impurities to which the water of wells is liable, derived from the soil in which they are sunk, they may receive foreign substances directly from their mouths. Surface floods may wash into them every kind of impurity, organic and inorganic; animals may fall in; persons suffering from painful diseases not unfrequently choose throwing themselves into a well as a convenient mode of suicide; the wind will blow in dust, leaves, etc.; foul vessels will be used for drawing water; dirty people may wash themselves at the edge.

Plate III.



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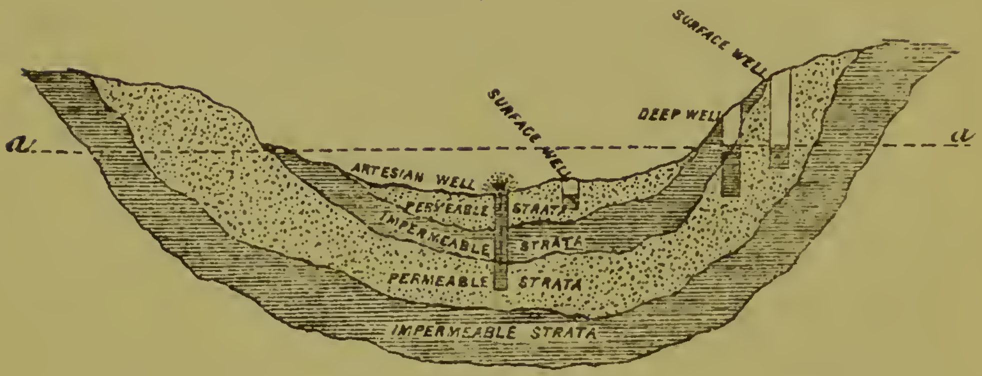

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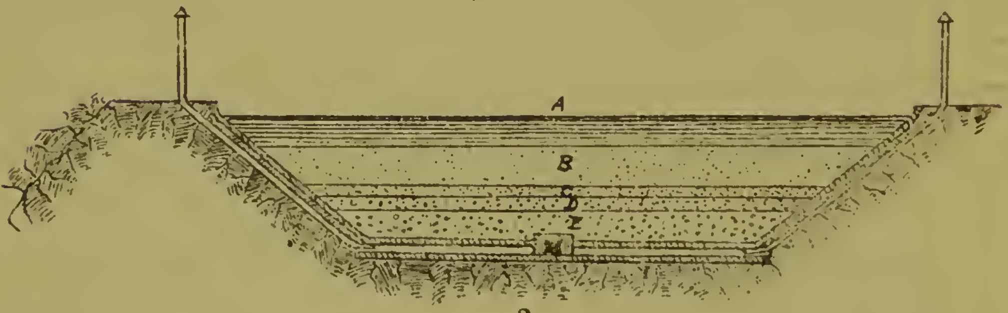

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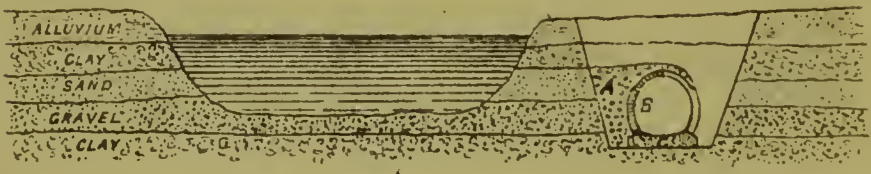

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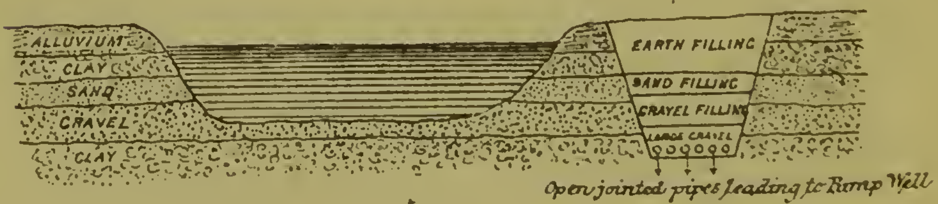

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To face p. 54.

PLATE III.

WATER SUPPLY, FILTRATION, Etc.

Figure 1. Deep Well shown (*a*) in elevation and (*b*) in section. The water is here derived from the *permeable* strata of sand and gravel enclosed between the two (practically) *impermeable* strata of clay. The masonry of the well is impermeable as far as the bottom of the upper stratum of clay, open-jointed through the two following strata, to allow of the passage of the water, whilst the bottom of the well is made of solid concrete bedded in the lower stratum of clay.

Figure 2. Diagrammatic section through a Valley, showing the Arrangement of the Strata, and illustrating how a Well is 'Shallow', 'Deep,' or 'Artesian' according to circumstances.

Figure 3. Section through a 'Filtration Reservoir,' where the water is filtered *downwards* through layers of sand and gravel (after Clark). A. Water to be filtered; B. 24″ layer of coarse siliceous sand; C. 6″ layer of coarse sand or of fine gravel the size of peas or dhâl; D. 6″ layer of coarser gravel the size of small limes; E. 12″ layer of rubble stones the size of oranges and small cocoanuts. Underneath the lowest layer are open-jointed drains connected with the pipe (shown in section) which leads the filtered water to the pure-water reservoir. The impurities in the water are nearly all retained by the first two or three inches of the sand, and a thin slimy pellicle is formed on the surface which offers a most effective barrier to micro-organisms, etc. (Koch).

Figures 4 & 5. To illustrate the 'Interception' System of Water Supply by a process of Natural Filtration. In both cases the river from which the supply is to be taken is seen in section, as also the strata of the soil in which the bed of the river is formed. A channel of the requisite length is dug at a certain distance from the river and parallel with it. In this is laid either a large aqueduct with one of its sides open-jointed (fig. 4, *s*) or else a series of small open-jointed pipes (fig. 5). Into these the water from the river flows through the *natural filter* made by the strata of sand and gravel between beds of clay, and finally runs into one or more wells, from which it is pumped up for use. After the work of laying the aqueduct, etc., is finished the channel is carefully filled up, as shewn in fig. 5, to prevent the water from contamination.

Wells sunk in granite, metamorphic rock or basalt generally yield pure water; in most cases, however, sand, gravel or alluvium is the material through which the water percolates; the last of which is the least desirable. Choice of soil in which to dig a well is rarely afforded, and, in general, it is only possible to preserve wells already existing from avoidable pollution and to select for use those which are free from obvious external sources of impurity. Thus the neighbourhood of burial-grounds, cess-pools, sewers or ill-constructed surface-drains, nullahs (invariably used as latrines), tanneries and slaughter-houses, unclean dwellings, stagnant surface pools or tanks in which human beings or animals habitually bathe or clothes are washed, fields which are freely manured, should be avoided in choosing a well for domestic use. The surface around, within the drainage area, should be kept free from animal and vegetable refuse, and should be carefully drained, so as to afford no lodgment to water. The mouth of the well should be protected by a parapet, and an impermeable platform sloping from its base and provided with a drain, so that spilled water may not return to the well. Should cattle be used for drawing the water, the path in which they travel must be drained and kept clean. The well should be covered with a shed as low as is compatible with convenience in drawing water, and the aperture should be restricted by the same limit; indeed, it is desirable that wells of average depth should be completely covered in and their water drawn by a pump. When a bucket is used, wood or galvanized iron is preferable to leather; and no private vessel should be employed, because there can be no security for its freedom from dirt, and it is probable that cholera and other diseases are thus disseminated. The vessel for general use should be examined frequently, and cleaned when necessary. Lastly, a well which has been long disused should, if required for use, be emptied, cleaned, allowed to refill, and the fresh water left long enough to deposit suspended matters.

DISTRIBUTION OF WATER.

Reservoirs are placed if possible at a higher level than the town so that the water has sufficient 'head' to allow of its flowing along the distributing channel, but in some cases, *e.g.*, where the supply is from a river close to the town, it is necessary to erect a pumping station by which the water is raised artificially to the necessary height.* From the reservoirs the water passes out, after secondary filtration into a smaller reservoir if necessary, by means of a curved pipe which opens at the middle depth of the reservoir so as to avoid both sediment and floating matter. From this pipe it enters the *aqueduct* which may be an open channel† but is preferably a closed iron pipe. Some of these aqueducts are of immense length, *e.g.*, that of the Glasgow water-supply from Lock Katrine which is more than 25 miles long and cost £468,000. In some cases supplementary service reservoirs are placed at the higher parts of the town to facilitate and regulate the distribution of water but more frequently the aqueduct leads directly to the smaller pipes which run along the streets and are known as the *distributing conduits* and *mains*. If there is a wet system of sewerage in the town it is important to lay the water mains as far as possible from the sewer-pipes for fear of leakage and contamination. From the mains the smaller *service pipes* carry the water to the houses where the *house pipes* convey the water, if the pressure is sufficient, all over the house. As regards material, all the pipes with the exception of the house pipes are made of iron as a rule and are frequently coated internally with bituminous or other substances to prevent contamination of the water. The house pipes are usually made of lead on account of the numerous turns necessary in leading the water through the house, but, however convenient in practice, it cannot be deemed a suitable material from a hygienic point of view.

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* This can be most conveniently done in places where the *Shone* system of wet sewerage is in use, by means of compressed air, as at Rangoon.

† As in Madras *v.* Appendix. Water supply of Madras.

In the early days of improved water supply in England the water was delivered on what is known as the INTERMITTENT SYSTEM which is still continued in a few towns but is rapidly falling into disuse.* Under this system water is delivered only at certain times, generally in the morning and evening and for an hour or two only, the supply being then cut off in order to save waste. Each house must have one or more cisterns in which to store a supply of water for use until such time as it is turned on again at the water-works. The principle disadvantages of this system are as follows: (1) The presence of cisterns in a house: they are almost certain to become foul. (2) The water is stagnant and absorbs impurities, *e.g.*, Sewer gas. (3) The supply pipes are left empty and are thus liable to draw in impurities, liquid or gaseous, by suction. (4) The pipes are exposed alternately to the action of air and water and are thus more likely to become corroded and the water rendered impure by metallic impurities, such as lead. (5) In the event of a fire occurring in the neighbourhood there may be no water at hand to quench it. (6) The noise of the water rushing into the cisterns twice a day is often distressing to invalids, particularly in small houses. If cisterns must be used, they should be of suitable material,† covered but ventilated, situated in a convenient place for inspection, *e.g.*, the roof of the house, and when the wet system of sewerage prevails a small and entirely separate cistern for flushing the water closets must be provided. They should be frequently inspected and cleaned. Under the CONSTANT SERVICE SYSTEM, which has almost entirely replaced the Intermittent, these evils are reduced to a minimum. Here the supply pipes are constantly kept full under considerable pressure, so that water can be obtained at any time and in any amount by simply turning

* Not necessarily in the East. In Calcutta there is an intermittent water-supply, during 14 hours daily, of over 44 gallons per head. (*v.* appendix). When an unlimited supply of clean water is furnished to an ignorant population, they are very apt to go to the opposite extreme from their usual habits; from the common use of a filthy pool to reckless individual waste of good water.

† *v.* under Storage of Water.

a tap. In order to prevent leakage the fittings must be very good, and meters or gauges must be placed on the pipes at intervals so that waste of water in any particular instance may be detected. Cisterns with all their attendant evils are, of course, under this system unnecessary.

Save in the largest towns, the distribution of water throughout India is at present almost entirely by the Direct Method. Owing to caste rules and other social customs the water for each household is drawn from a tank, well, or stream by some member of that household. In this way a careless or ignorant person may endanger the lives of many others by the use of a dirty utensil. The possibility of such an occurrence should be prevented as far as possible. In times of water-famine, disputes between different castes as to the exclusive right of use of particular wells are frequent and are the cause of much cruelty and injustice being done to the inferior caste. On the line of march and in action the services of the *pakâli* and *bhisti* will always be required and they cannot yet be dispensed with in mufasil hospitals and barracks. Their water-skins require frequent and careful inspection.*

The Quantity of Water Required.—The quantity of water necessary for health, directly or indirectly, is next to be considered and also the various purposes for which it is required. The golden rule of course is to supply a practically unlimited amount of pure water whatever be the use it is to be put to. But this is not always possible, hence the necessity for considering the minimum compatible with health. Accurate experiments in India on this matter, as on nearly every other matter connected with the details of hygiene, appear to be wanting. The manner in which the supply is obtained has a great effect upon the quantity used. If water has to be drawn from deep wells or even pumped up by members of the household, much less will be considered necessary for health and comfort. If the supply is constant and requires only the turning of a tap, there will be

* *v.* Impurities of water.

more or less waste, and the quantity consumed will exceed the quantity really required. Except on boardship it rarely happens that an attempt is made to distribute to each individual or to each family the theoretical ration, but it is frequently calculated per head for the population of a town by dividing the total amount available or supplied, by the total population of the town. The following table gives a fair idea of the average quantity required per head in an English manufacturing town and the various purposes for which it is needed.

	Gallons per head daily.
A. *Domestic Use:*	
1. Drinking (besides which 30-50 ozs. is taken in bread, meat, etc.) ...	0·33
2. Cooking	0·75
3. Ablution, including bath (2½ galls.) ...	5·00
4. Share of utensil and house-washing...	3·00
5. Share of clothes-washing	3·00
6. Water-closets	6·00
7. General bath (weekly about 30 galls.)	4·00
8. Unavoidable waste	3·00
	25·08
B. *Town and Trade purposes:*	
9. Washing streets, etc., extinguishing fires, supplying fountains and drinking troughs, etc., allowance for trade and for animals	5·00
10. Allowance for exceptional manufactures.	5·00
	10·00
Total...	35·08

In India more will be required for most purposes, particularly bathing, but none directly under the items 5 and 6, and very little under 10, save in special cases.

The water required for food is partly drunk and partly sued for cooking. Under ordinary circumstances of tem-

perature and exertion 0·4 gallon will be sufficient for the former purpose for a man in 24 hours. More will be required if the heat is great, or the exertion undergone severe. As women and children drink absolutely less than men, this allowance will be sufficient when supplied for each of the residents of a barrack, jail or town, or the members of a household of average composition. For cooking 0·6 gallon will generally be a sufficient allowance, making the total for food one gallon daily for each individual, and this is the quantity found necessary on boardship in the tropical seas. As a general rule, the water supplied for the two food purposes will be the same, but a difference may sometimes be compulsory. In this case it is to be remembered that saline waters unfit to drink may be freely used for cooking; and, on the other hand, that water of considerable temporary hardness may be palatable and wholesome to drink but unsuited to culinary use.

Washing of persons and cattle, clothing, houses, furniture and utensils is of very great importance to health, and ample provision should be made for it. For bathing the quantity needed varies considerably, a bath-tub requiring at least 30 gallons for comfort and often containing more than 50, while 12 gallons poured over the body from chatties affords a bath considered amply sufficient by many persons, and four gallons are enough for a sponge-bath. A plunge-bath measuring 20 feet by 12 by 5 holds 7,500 gallons of water, and if supplied continuously, so that it it should receive in two, or even in three days that amount of fresh water (entering above at one end and issuing below at the other), will provide ample means of ablution for a regiment, or the inmates of a large jail. In this country, where a complete bath daily is habitually taken and is necessary to health, provision for minor ablutions may be considered as included in the estimate for baths. The quality of bath-water is comparatively of little importance; it should be *water* however, and not the filthy putrescent liquid which fills so many of the tanks, sacred or

otherwise, of India. It should not be muddy; and if it is too salt or too hard soap will be wasted.

The customs of the country relieve us from the necessity of providing water for the washing of clothing, for which dhobies are trusted to make their own arrangements, such arrangements being almost invariably insanitary and disgusting in the highest degree. As regards dwellings, floors of earth or plaster will not admit of washing; and walls, unless finished with polished chunam, are cleaned by sweeping or by a fresh coat of lime-wash. An allowance of two gallons per head will be ample for the maintenance of houses, jails or barracks in a state of proper cleanliness. For utensils three gallons will be sufficient.

It is apparent from the foregoing paragraphs that the total quantity of water necessary for a community varies within very wide limits according to circumstances. It is useless, therefore, to attempt to lay down precisely any general rule. The figures given above afford the means of estimating total requirements in any particular case.

Hitherto the wants of persons in ordinary health have been considered. Hospitals require a much more copious water-supply, in proportion to their number of inmates, than other dwellings. More water is drunk, more liquid food is consumed, baths are more frequent and more abundant, the boiling of clothing and bedding before sending them to be washed is often desirable, extreme cleanliness of floors, walls, cots and utensils of all kinds is essential, irrigation and washing of wounds, bruises, etc., consume a large amount of water. The supply to a hospital, therefore, should, if possible, be unlimited and waste is a less evil than even trifling deficiency. Should the total supply be limited, economy should be practised at the expense of the healthy, and the hospital amply provided. If it should be necessary to make an estimate for hospital use, 30 gallons per head will not be excessive for drinking, cooking, bathing and washing.

The quantity of water which should daily pass through sewers, in order to maintain their cleanliness, cannot be fixed: so much depends on their fall and shape and on the materials which are permitted to enter them. When solid and liquid excreta have to be removed by them, a minimum of 25 gallons per head daily (besides rain) has been laid down; but this is a case with which we are not likely to be called upon to deal. As a rule, our sewers will contain only the liquid refuse of the cook-rooms, the washings of houses and utensils, and the water which has been used for bathing; and the last will generally be sufficient, with ordinarily well constructed sewerage, to dilute and remove the others. Sewers will require watching to ensure their freedom from obstruction and from consequent generation of noxious or unpleasant gases; and flushing copiously with water of any kind will be the remedy, when they become foul. *The best test of the satisfactory state of sewers is not the quantity of liquid which they receive, but the quality of the discharge at their out-fall.* When this is scanty, semi-solid or offensive, careful cleansing followed by free flushing is indicated.

Provision has to be made for cattle also, both for their drink and for the preparation of their food. The quantity required for the former will vary, as in the case of men, with temperature and work; but the following numbers may be taken as applicable to ordinary circumstances in this country:—

Horse	8 gallons.
Bullock or cow	8 do.
Mule	6 do.
Pony	6 do.
Elephant	30 do.
Camel	12 do.
Sheep	1 do.
Pig	1 do.

Unless water of the best quality is scarce, it should be supplied to cattle for their drink. When they are fed on

chenna which requires only steeping in cold water for its preparation, or when *khulti* is used without boiling, a gallon of water may be allowed for four "measures" of the food; when boiling is considered necessary, the allowance should be two gallons. As regards the quality of the water used for this purpose, the same remarks apply as in the case of preparing human food.

If it be necessary to make provision for the washing of other animals (to whose health and efficiency a clean skin is scarcely less essential than it is to their owners') two gallons should be allowed for a horse, bullock, cow or buffalo, and corresponding quantities for others in proportion to their size.

The effects of Insufficient Supply of water are closely connected with those of impure supply, and also with those of a polluted atmosphere. Absolute privation of water for drinking need not be considered here; partial privation is productive of so much inconvenience or suffering that any kind of water will be drunk—even from the foulest pools—to satisfy thirst. Not only, however, does this indirect evil consequence follow from want of drink, but also great muscular debility, with disinclination to and incapacity for exertion. It follows that a constant supply of the best drinking water available is essential to the efficient performance of labor of every kind, and that for soldiers on march or in action, for coolies at work, or for prisoners undergoing really hard labor, water should always be at hand to compensate the loss by lungs and skin. Under such circumstances, water should be, not merely procurable, but conveniently obtainable at any moment, so that the needful supply may be taken in small quantities from time to time, not in copious draughts at once. When water for cooking is insufficient, the processes necessary to the digestibility of food will be unsatisfactorily performed; or the same water used more than once will be more liable to putrefactive changes and consequently more likely to act injuriously both through stomach and lungs than if it were

used once only and then removed. It is unnecessary to dwell upon the necessity of cleanliness to health. Insufficiency of water for personal ablution is incompatible with the due action of the skin which, in hot climates more especially, is of vital importance, and skin diseases as well as a generally depressed state of health will inevitably follow; while the atmosphere is polluted by effluvia, in great part organic, from unwashed or imperfectly washed clothes, furniture and utensils. People can be 'educated up,' as it were, to the use of sufficient water, as is well seen in England, since the introduction of a suitable water supply in towns and country districts. Lastly, if the water supply is insufficient for other purposes, it must be altogether inadequate to the free removal of refuse by the sewers. If these are intended to convey not only water which has been used but also excreta, the propagation of enteric fever, cholera and other diseases, and *possibly* the origination of the first and others, will be favored by the clogging of the sewers and the drying of their contents. In ordinary cases the air will be poisoned by noxious gases and organic effluvia generated in uncleared sewers.

THE COMPOSITION, IMPURITIES AND CLASSIFICATION OF DRINKING WATERS.

It is neither necessary nor desirable that water used for drinking or other domestic purposes should be absolutely pure. Such water would be insipid and perhaps unwholesome. Impurity to a certain extent is practically inevitable and neither disagreeable to the taste nor injurious to the health. A good water then is not one which is chemically pure, but one which is *transparent, colorless, odorless* and *tasteless,* which holds in solution a *sufficient amount of atmospheric air,* which contains *no suspended matters* and *no excess of total solids* nor of any particular substance dissolved.* The

* Good water, though tasteless, has a peculiar quality due to the dissolved gases, oxygen, nitrogen and carbonic acid, more especially the last: the absence of such gases rendering a water 'flat,' as in the case of distilled water. When carbonic acid is present in excess, as in soda-water, the water is said to be 'aërated.'

Impurities in water are either Suspended or Dissolved and may be roughly classified thus :—

In Suspension.

Particles of animal, vegetable and mineral origin.

Microbes and other living organisms, vegetable and animal.

In Solution.

Gases.

Mineral salts.

Soluble organic matter of animal and vegetable origin.

SUSPENDED IMPURITIES are Inorganic or Organic. Inorganic impurities may consist of very finely divided silica, clay, chalk, chalky marl, ferric oxide, magnesium carbonate or other mineral substances. Rivers, especially in time of flood, carry down variable quantities of suspended matters, mostly inorganic. Thus the Rhine water contains from 1·73 to 20 parts in 100,000 ; the Mississippi from 58·82 to 80·32 ; the Ganges from March to June 21·71, from June to October 194·3, from October to March 44·86 ; the mean proportion of suspended matter being 86·86 in 100,000. Tank and shallow well waters also, especially after rain, are turbid from this cause. Such waters containing suspended mineral matters in excess may produce diarrhœa, dysentery, and even ulceration of the intestine, to which persons not accustomed to their use will be more liable. Organic impurities are more varied and more important. The *débris* of animal and vegetable organisms ; ova, seeds and germs ; living animalcules and plants of a low order ; fæcal and other excrementitious matters ; the specific poisons by which cholera and many other diseases are propagated—all these may be amongst the impurities suspended in water. Even rain water may contain some of these, but all of them may be carried from the surface into tanks and rivers or washed into wells by floods or percolate into them through the soil. Microbes of all kinds and in any number may be present. The great majority of these are probably harm-

less; many are undoubtedly useful as purifying agents, whilst others again, as the immediate cause of specific diseases, may work deadly mischief by their presence.

DISSOLVED IMPURITIES may be Gaseous or Solid, the latter being organic or inorganic. The Gaseous substances requiring to be noticed are *air, carbonic acid, ammonia, sulphuretted hydrogen* and *marsh-gas.*

The presence of AIR or, to speak more correctly, of a variable mixture of oxygen and nitrogen, rarely containing the same proportions as the atmosphere, is necessary to render water palatable and readily digestible. The oxygen is more readily absorbed by water than the nitrogen and it is also evolved by certain water plants; hence it may amount to as much as 32 per cent. of the total quantity of both gases present. Neither can do any harm, while the oxygen is useful by converting decomposing animal and vegetable substances into innoccuous compounds. Water is rarely deficient of air; but when (as in distilled water) there is a deficiency, it should be artificially supplied, either by forcing air into the water or by letting the latter fall in divided streams, as through holes bored in a cask, from as great a height as possible, through air.* We may infer the presence of much oxygen if we have reason to believe that carbonic acid is present in abundance, unless in the case when the latter is formed from organic matter at the expense of the former.

CARBONIC ACID gives a sparkling appearance and a pleasant taste to water, and it can only be injurious by enabling water to hold in solution large quantities of carbonates of calcium, magnesium, etc. It may be derived (1) from decomposition of carbonates by subterranean heat, as in the case of carbonated springs; or (2) by absorption from the atmosphere, one volume of water at 20°·0 being capable of absorbing 0·901 of this gas; or (3) from the soil through which the water percolates, the air in which

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* *v.* p. 52.

contains in some instances 250 times the normal proportion of carbonic acid; or (4) from the slow combination of the carbon of organic substances in the water with oxygen, in which case it represents putrescible and possibly injurious matter destroyed. Its amount in ordinary water varies from 3 to 300 c. c. per litre or parts per 1000. It is known to be present in considerable quantity when bubbles are seen on the inside of a glass vessel in which water is permitted to remain for some hours. Present in large amount it sometimes gives an acid reaction to test paper, the acidity being removed by boiling. Boiling removes it and the greater part of other gases; lime combines with it, the carbonate thus formed and other carbonates held in solution by it being precipitated.

Free Ammonia is derived from the decomposition of nitrogenous organic matters, chiefly animal, in the water itself or in the soil through which it percolates, or from the atmosphere through which it falls. It is almost invariably present in ordinary waters. It is not in itself mischievous, but its presence in large amount indicates serious organic contamination. If present with nitrates or nitrites, or both, it is probably due to the decomposition of animal matters. If nitrites in abundance and ammonia co-exist the contamination is probably recent. Its odor betrays its presence if the quantity be considerable. Turmeric paper browned by alkaline water recovers its colour on exposure to air if the alkalinity was due to free ammonia. The reagent known as Nessler's solution will detect the presence of minute quantities of free ammonia by giving the water a yellowish coloration when added, or even throwing down a brown precipitate if the ammonia is present in large amount.* Filtration through fresh charcoal will remove ammonia from water and, to a great extent, the organic matter which generates it.

Sulphuretted Hydrogen.—When water contains a sulphate in solution (as that of calcium or of sodium) and also

* v. under Examination of Water.

organic matter, the latter takes oxygen and converts the sulphate into a sulphide; or a mineral sulphide such as pyrites may be present. This again being decomposed by a free acid, (probably organic, possibly by carbonic acid), Sulphuretted Hydrogen is the result. It is also one of the products of the putrefaction of albumen. Water in contact with it at 15° absorbs 3·23 volumes. The peculiar odor of this gas renders its presence even in small quantity readily perceptible, especially with the aid of gentle heat, and a solution of lead acetate in solution of soda gives a black or brown color with water which contains it. Boiling, agitation, exposure to air in divided streams, filtration through charcoal or addition of lime removes it from water.

Marsh-gas is evolved in the slow decomposition of vegetable matter, air being excluded; but is only very slightly soluble in water. It would be found in marsh waters; and certain foul river waters, that of the Thames for instance, undergo when kept for a few days a kind of fermentative purification, during which great part of their organic impurity is given off in the form of marsh-gas and sulphuretted hydrogen. It may leak into water from gas-pipes There is no reason to suppose that its presence in drinking water is mischievous. Boiling or exposure to air in divided streams frees water from it.

Dissolved Solid impurities are organic or inorganic; the former being the more important. The presence of Organic matter in solution is almost inevitable. Even rain dissolves and carries down some from the atmosphere and water which has percolated through the purest granitic or clay-slate soils may contain from four to ten milligrams per litre. Water collected from rich cultivated soils sometimes yields a volatile residue of 4 to 7 ctgms. per litre (parts per 100,000) or even more, while this amount is considerably exceeded in peat waters and marshes. In these cases the impurity is chiefly or wholly of *vegetable* origin, consisting of humin, ulmin and organic acids derived from these, none

of which contain nitrogen, though the acids readily form ammonium salts when the base is supplied. *Animal* organic matter passes readily into waters derived from the neighbourhood of dwellings, which have washed or percolated through filth-soaked ground, or which have been polluted by communication with cess-pools or other accumulations of impurities. Dead animals slowly decompose in rivers, tanks and wells, and water from burial-grounds finds its way into sources of supply. Urea readily becomes ammonium carbonate, and a large proportion of the products of decomposition of animal substances contains nitrogen, which forms ammonia in the soil, and this is oxidized, with greater or less rapidity, to nitrous and nitric acids. Hence, water which has been exposed to pollution by animal impurities may contain in solution not only free ammonia but ammonium salts, nitrites and nitrates. Again, the decomposition of bodies of animals produces certain fatty acids, butyric and others, not nitrogenous, which form, with calcium and other bases of the soil, salts soluble in water; and these are probably not the least important dissolved impurities of organic origin. But little, however, is really known of the exact nature of the organic matter in water, for it is usually small in amount, unstable, varies much in its chemical composition and is highly complex.

Closely connected with the organic matters in solution into the composition of which nitrogen enters, are AMMONIA, NITROUS ACID and NITRIC ACID. The presence of any one of these implies, as a general rule, the previous solution of nitrogenous organic matter in the water. Though, therefore, none of them (except, perhaps, the second) is directly injurious to health, it is important to ascertain their presence and amount. Free ammonia has been considered already. The presence of nitrites in large proportion indicates a probable recent contamination with animal organic matter. They are easily oxidisable into nitrates. The presence of nitrates generally points to animal contamination. If no nitrites and little ammonia be pre-

sent at the same time, the nitrates of potassium, sodium and calcium probably indicate that the contamination is of long previous occurrence. So too, nitrates in abundance with little oxidizable matter, indicate old animal impurity. The process of 'nitrification,' *i.e.*, the oxidisation of organic matter with the formation of nitrates, seems to be largely dependant on the action of microbes of several kinds, nitrites being primarily produced by the action of a particular micro-organism, and these being changed into nitrates by another microbe.* The nitrates are gradually removed and assimilated by the roots of growing plants.

The Inorganic dissolved impurities consist of mineral salts in solution derived from the strata through which the water has passed. In analysing these substances the various acids and bases can only be detected individually, the mode of combination being uncertain.

The chief ones are as follows:—Sodium, potassium, calcium, magnesium, iron and lead, in combination with chlorine, sulphuric, nitrous, nitric, phosphoric, carbonic or silicic acid. The most usual combinations are sodium chloride, sodium sulphate, sodium carbonate, calcium carbonate (held in solution by carbonic acid), calcium sulphate, calcium chloride and silicate, and magnesium carbonate; but the results of analysis may render other combinations necessary.† In addition, certain metals such as arsenic, magnesia, iron, lead, zinc and copper may be present: of these iron and lead are the most important practically, especially the latter. SULPHURIC and CARBONIC ACIDS will be considered in connection with the bases with which they are found in combination. NITROUS and NITRIC ACIDS have already been discussed.‡

CHLORINE is almost invariably present in natural waters, in combination with the alkaline metals or calcium. Even

* The oxidising power of the organisms in soil is by no means limited to the oxidation of ammonia or of organic matter, *e.g.*, iodides and bromides may be oxidised into iodates and bromates. *v.* Thorpe, Dict. of App. Chem., Vol. II, p. 699.

† *v.* Parkes—Notter, *ibid.*, p. 49. ‡ *v.* previous page.

rain water has been found to contain as much as 0·020 grm. of sodium chloride (0·012 grm. chlorine) per litre derived from sea-spray and which has been carried hundreds of miles inland by winds. This is one source of the presence of this salt in other waters ultimately derived from rain. Formations deposited originally in sea-beds or salt lakes undergoing a process of dessication (?) retain the sea-salts, including magnesium, potassium and especially sodium chlorides: and occasionally the latter two are found in mass.* Direct percolation from the sea is another source of chlorine in other waters. Lastly, sewage containing the excreta of men and animals includes a large proportion of sodium and other chlorides, which it imparts to water in contact or communication with it. It is owing to this last possible origin of chlorine in drinking waters that an exaggerated degree of importance has been attached to its presence. This is its least likely source, in this country at any rate; and its derivation from such organic contamination will always be indicated by the accompanying presence of other products of sewage pollution.

Waters not unfrequently contain phosphates in solution and, as these may have been derived from sewage or from animal remains as well as from harmless minerals in the soil, it is desirable to ascertain whether Phosphoric Acid is present.

The silicates of soda and alumina are sometimes present but there is no reason to suppose that Silicic Acid is of any importance from a sanitary point of view. Some, however, consider that in its absence water is enabled to exert a solvent influence on lead.†

Calcium is the most important of the bases found in water, whether used for drinking, cooking or washing. It is the principal cause of *hardness*, which, if excessive,

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* For interesting account of various salt-formations in India, *v.* Geology of India. Pts. I and II.

† *v.* Lead, p. 74.

renders water unfit for culinary purposes and causes great waste of soap in the cleansing of the person or of clothes. Its salts, so far as our purpose is concerned, are the carbonate on one hand, removable almost completely by boiling, and the sulphate, chloride, nitrite, nitrate and butyrate on the other; the latter group (to which the hydrate may be added) remaining in solution after the carbonate has been precipitated. As water percolates through soils it dissolves out more or less completely the lime salts almost always present. Spring, well or river water, therefore, generally holds calcium compounds in solution, and even rain water is rarely free from traces of them derived from the atmosphere.

It has been already stated that calcium exists in water in two kinds of combination and the distinction is of great importance both from the sanitary and from the economic point of view. Calcium carbonate is soluble in pure water only to a slight extent, about 30 milligrams per litre, but is freely soluble in water holding carbonic acid in solution. Rain as it falls takes up this acid from the atmosphere, and, as it percolates through the soil, the interstices of which often contain air highly charged with carbonic acid, it absorbs still more. The water thus becomes a solvent of any carbonate of calcium (and also of carbonate of magnesium or of iron) which it meets in the soil. Hence the water of chalk or limestone formations holds always a considerable and sometimes a very large proportion of calcium carbonate in solution, by means of carbonic acid. The expulsion or neutralization of this acid necessarily destroys the solvency of the water, and, as this can be effected by boiling (which drives off the acid) or by adding lime (which combines with it) this lime salt is readily removable from water. Hence hardness depending on the presence of carbonates thus held in solution is called *removable* or *temporary* hardness; and, as calcium salts are the principal cause of total hardness, so *calcium carbonate is the principal cause of temporary hardness.*

The presence of this salt will be made evident by boiling the water for half an hour in a glass flask. The carbonic acid will be thus driven off and any carbonates present thrown down. Another means of removing calcium carbonate, so far as its presence depends on free carbonic acid, is by 'clarking' the water, as it is called. Mr. Clark's process consists in adding lime to the water, which combines with the free carbonic acid to form carbonate, which, along with the carbonate which is now thrown out of solution, gradually subsides; carrying with it, as we shall see,* organic and other matters in suspension. It must be borne in mind that this process removes temporary hardness only, while it adds slightly to the permanent hardness, to the extent of the lime which is taken into solution. It is applicable, therefore, to waters containing a large quantity of carbonates in solution and not containing an excess of other calcium salts.

The other calcium salts, which are not precipitated by boiling, are more important than the carbonate, because their effect upon the health, even in small quantities, is injurious; while they are equally objectionable economically. The Sulphate is the most common, and next to this the Chloride, Nitrate and Nitrite. *The permanent hardness of water is mainly due to these salts,* which remain in solution after the carbonate has been precipitated by boiling or the addition of lime. Organic fatty matters undergoing putrefaction often generate butyric acid, which, itself highly irritating, combines with calcium to form a poisonous butyrate.

MAGNESIUM is a much rarer impurity than calcium; but it is found in water from many Indian stations.† Its salts are second in importance, as causes of hardness, but their presence in excess is very likely to produce intestinal derangement. When water is boiled to expel carbonic acid

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* *v.* Purification of water.
† *e.g.*, Coimbatore, Salem and Bellary in the Madras Presidency.

magnesium carbonate is deposited with calcium carbonate, but as the water cools, the former is re-dissolved.

IRON is a third cause of hardness. Few of our waters are altogether free from it and it is present in most cases as the carbonate, held in solution by free carbonic acid, whence it follows that it is thrown down by boiling, along with the calcium and magnesium carbonates. *Taste* detects a smaller quantity of iron than of any other impurity, and it is said that 3 mgms. per litre give an appreciable chalybeate flavor. Boiling, lime and perhaps filtration remove it.

The SODIUM salts generally found in water are the chloride and the sulphate, and it is usual to suppose all the chlorine combined with sodium if the latter is present in sufficient quantity. The presence of common salt in water, unless largely in excess is, in itself, rather beneficial, especially in India. It *may* be derived from sewage contamination, especially recent contamination with urine, but in the majority of instances in this country it has no such origin. When so derived other evidences of pollution cannot fail to be present. It may be partly removed from water by filtration through a considerable thickness of sand and charcoal, and in this way brackish water may be rendered fit for use. The sulphate is not likely to be present in hurtful amount, but the carbonate if present in a proportion of more than 3 dgms. per litre (0·3 parts per 1,000 of water) renders the water unfit for continued use.

LEAD salts are occasionally found in natural waters, but most commonly in water which has passed through leaden pipes or been kept in leaden cisterns. The solvent action of water on lead depends upon the nature of the impurities which the former contains: water absolutely pure being itself, in the absence of air, incapable of acting on the metal. Any impurity which forms, directly or by decomposition, a soluble lead compound favors lead contamination. Thus water containing oxygen, air, organic acids (animal or vegetable), nitrites, nitrates or chlorides

should not be kept in contact with lead. Hence rain water, water containing sewage, or water which has lain on rich vegetable mud should not be conveyed or stored in lead. Others again attribute the solvent action of some water to the presence of certain micro-organisms; yet others to the absence of silica from the water.* The matter is still undecided.

On the other hand an impurity which forms an insoluble lead salt, or which deposits a coating impervious to water upon the metallic surface, exercises protective influence against lead poisoning. In this way carbonic and, sulphuric acids, or decomposable carbonates and sulphates, forming insoluble lead salts protect from the usual consequences of the presence of lead—with this exception, that if free carbonic acid is present it renders part of the lead carbonate soluble. Hard waters deposit a protective crust which is found to consist of the carbonates, sulphates and phosphates of lead, calcium and magnesium. Calcium phosphate is especially protective.

The symptoms of lead poisoning (Plumbism) ore so well known that they need not here be described.† The quantity of lead likely to produce intoxication varies with individual peculiarities, but any water containing more than 1 part per 1,000,000 is unfit for domestic use. It is obviously much better that there should be none. When lead is present at all, accident, carelessness or mismanagement may readily cause increase in its amount from a harmless to an injurious degree.

Numerous remedies have been proposed having one of two objects in view, *viz.*, either the neutralisation of the solvent action of the water or the substitution of some material other than lead in the construction of the water-pipes. As regards the first, the remedy obviously depends on the cause, hence the addition of powdered chalk or

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* *v.* Silica, p. 71.

† *v.* Quain's Dict. of Medicine, p. 812 *et seq.*

carbonate of lime to neutralise the excessive acidity of the water has been apparently successful in some cases. If the contaminated water is filtered through sufficiently active animal charcoal* the lead is removed, probably owing to the formation of an insoluble phosphate. As regards the substitutes for lead piping the following are the chief: lead pipes lined with block tin or a bituminous coating; iron pipes, plain or galvanised or coated internally with Angus Smith's varnish; finally, pipes made of 'rustless iron' by the Barff process, ordinary iron pipes being exposed, whilst hot, to superheated steam, the result being the formation of a thin coating of magnetic iron oxide, Fe_3O_4. A clean fresh surface of lead is most readily attacked, hence new pipes, or pipes much bent and thereby cracked superficially, or pipes which are alternately full and empty, yield most lead to the water. Where leaden pipes must be used the tap should be allowed to run for a little time before the water is drawn for use.

Water containing traces of Zinc, Arsenic or Copper has generally been polluted by accidental contamination and should always be rejected.

The Inorganic impurities in water are, with the exception of lead, mostly impurities of source, *i.e.*, they are present in the water before it is collected. The animal and vegetable impurities are generally added subsequently *i. e.*, impurities of storage or distribution. Water, especially in India, is extremely liable to be fouled during storage with disastrous results to the users of the water. There is perhaps, says Parkes "no point in which the attention of the Sanitary officer should be more constantly fixed than that of the storage of water either on a large or small scale." Where the distribution is by hand from a direct supply situated in a crowded street and common to all users the chances of added impurity are enormously increased. The water carriers of the East including the Indian *pakâli* and

* *v.* Filtration of Water.

bhisti deriving their water as they too often do from polluted sources and distributing it in filthy skins or barrels are undoubted and frequent disseminators of epidemic disease which is by no means confined to their customers, and in this matter their congener is the *dhobi*.

Varieties of Drinking Waters.—According as the source of a water supply varies so will the nature of the water vary.

RAIN water is wholesome by its purity and agreeable because highly aërated, containing from 3 to 30 c. c. of gas in a litre. The proportion of oxygen in the mixed gases is higher than in atmospheric air, amounting to 32—38 per cent. Carbonic acid contributes 2·5 to 3 per cent. Other substances are met in the atmosphere and dissolved or carried down mechanically. Thus ammonium carbonate and nitrate (the latter more especially during thunder-storms), phosphoric acid, hydrochloric acid (near the sea), sulphuretted hydrogen or soluble sulphides, free ammonia, sodium chloride (sometimes even as much as 2 centigrams in a litre) traces of potassium and calcium chlorides, calcium carbonate and calcium sulphate may be found in solution in rain water directly collected. Iron, alumina, silica, particles of carbon, light organic substances (as pollen) are found in suspension. Traces of nitrogenous organic matter derived partly from the atmosphere, partly probably from the surface on which the rain falls, are almost always present, and have been known to amount even to 8 milligrams per litre. The total solids of rain water may be taken at a mean of 32 milligrams per litre, the greatest quantity observed having been 0·0509 grm. The impurities of most importance are ammonia, free and albuminoid, and sulphuric acid, the last being sometimes styled a "measure of the sewage of the air." In India owing to the absence of coal-smoke in the atmosphere the amount of this latter impurity is probably very small. Free ammonia has been found to range from 0·180 to 9·1 mgrms. per litre; albuminoid from 0·034 to 0·4; sulphuric acid from 2·06 to 70·19.

Besides the impurities which rain water derives from the atmosphere through which it passes, it necessarily takes up others, and in larger quantity, from the 'receiving surface' on which it falls. When this is a roof—a flat one more especially—dust, organic and inorganic, excreta of birds, bones and feathers, dead insects, etc., contribute to the impurity of the supply. When the source of supply is a tank filled by surface drainage, all the impurities of the drainage area will, of course, be liable to be present in the water; and in this case rain water is no purer or better than the water of shallow wells. In the former case, where the rain is collected as it falls, the degree of pollution is insignificant, and the probability of the germs or poisons of specific diseases finding their way into the system through the drinking water is reduced almost to a minimum. It is desirable, therefore, that when there is no suitable indirect supply, this source of water-supply should be taken advantage of as much as possible, and that means should be adopted for the collection of all rain falling on the roofs of barracks, jails and other large buildings. Filtration through an oxidizing medium is still necessary before use.

Ice-water is 'flat' and unpalatable, but the usual addition in India of aërated waters to ice lessens this quality. In America the constant use of iced-water, *i.e.*, water frozen solid in vessels and then drunk whilst melting, is the cause of a considerable amount of dyspepsia.

The composition of Well-water depends upon the strata through which a well is sunk, the condition of the neighbouring surface and the measures taken to preserve the water from contamination.* According to circumstances, well-water may be thoroughly pure and wholesome, strongly medicinal, *i.e.*, full of mineral and gaseous impurities, or simply liquid sewage.†

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* *v.* Storage, p. 54.

† "Shallow well-water is the worst of all waters. Some of the shallow wells in or near villages are no better than cess-pools, and the people often drink their own diluted ordure and urine, mixed with those of the domestic

SPRINGS are supplied immediately by subterranean reservoirs which are themselves dependent upon the rain percolating through the strata overlying and surrounding them. The water which they yield is liable to the same kind of impurities as that of wells, though generally in a less degree; and most of the precautions and protection which the latter require are in many cases applicable to springs.

The usual sources of the numerous medicinal waters are deep natural springs from the mouth of which the water wells up continually, at any temperature up to boiling point; often highly charged with carbonic acid or sulphuretted hydrogen and holding in solution various salts such as magnesium sulphate (Epsom Salts) or sodium sulphate (Glauber's Salts), etc.

A STREAM or SMALL RIVER occasionally supplies water to a town or camp. In addition to the ordinary impurities of the springs which flow into it a stream is liable to pollution by surface drainage, dead organic matter, fæcal impurities washed in by floods, and suspended clay, etc., from the same source. The supply is precarious, the smaller streams, as a rule, drying up in the hot season (though water may always be found by digging in their beds). The beds when thus dry are liable to much pollution with organic and noxious material, which subsequently is taken up by the water. It is obvious, therefore, that a stream, especially if villages are situated on its banks above the position, is in general a most objectionable source of water-supply, and one indicating careful filtration or boiling as essential. The water from jungle streams though clear and appa-

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animals, and the washings of their bodies, clothes and household utensils, along with all the other dirt which may find its way into the water from the surface and from the air. What wonder that such people are never free from internal parasites, and that they are debilitated and die by millions from diarrhœa, dysentery, cholera and fevers? What wonder that their soil should be the "breeding ground of cholera"? * * * * * One of the most urgent and primary sanitary measures required every where in India is the filling up of surface pools and dangerous shallow wells."—MCNALLY.

rently pure, is considered dangerous by many, as it appears to be the frequent vehicle of malaria. This point is unsettled as yet. It occasionally happens that troops marching through an uninhabited or thinly-peopled country may find in a stream a convenient and wholesome supply. In such a case precautions should be taken to preserve it from being fouled by the cattle of the camp or by washing clothes or persons in it at any points above the most convenient part for obtaining water for drinking and cooking. The spot best suited for this purpose having been selected, another for watering cattle, lower down the stream, should be chosen, and a third, below this, for washing of every kind.*

Many populations are dependent upon RIVERS for their water-supply. In this country the periodical rains and the habits of the people often render this source of supply highly unsatisfactory. In time of flood rivers bring down suspended clay, sand, etc., in large quantities, besides the washings of their beds, fouled with every impurity during the dry season, and of the nullahs which open into them. Dead bodies are often thrown into rivers, and the sewage of towns and drainage from tanneries, slaughter-houses, dye-works, etc., are conducted into them. On the other hand the impurities are largely diluted, while the continual exposure of fresh surfaces to the air promotes the oxidation of putrescent organic matter† and the deposition of carbonates held in solution by carbonic acid. It is evident that water taken directly from rivers, especially in time of flood, should be carefully filtered before use; or, if this be impracticable, it should be well boiled.

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* An excellent plan to obtain good water from a shallow river is to dig small pits or shallow wells some distance from the water's edge. These depressions gradually become filled with clean filtered water.

† The actual amount of oxidation of impurities which take place in running water is still a matter of dispute. It is certainly not so great as was formerly supposed. When the water is very much polluted the effect of oxidation is trifling. Subsidence of suspended matters takes place to a certain extent and the process of purification (oxidation ?) is also assisted by water plants and micro-organisms (?).

The following table* gives a good idea of the comparative merits of the different sources of drinking water (in England).

Wholesome.	1. Springwater. 2. Deep well water. 3. Upland surface water.
Suspicious.	4. Stored rain water. 5. Surface water from cultivated land.
Dangerous.	6. River water to which sewage gains access. 7. Shallow well water.

As regards palatability 1 & 2 are very palatable.
3 & 4 ,, moderately ,,
5, 6 & 7 ,, ,,

These tables probably hold good for India with the exception of No. 3 (upland surface water) which is considered dangerous by some as being a favourite vehicle for malaria, save at great elevations, *e.g.*, the Nilgiri plateau (7,000 feet).

Not only the quantity of the water derived from the sources already considered, but also its quality, varies widely with the *season*, and this point has to be considered in judging of the fitness of a tank, well, spring, stream or river for supplying particular wants. In dry weather evaporation concentrates water, increasing the proportion of solid impurities, and the accompanying heat favors putrefaction of organic matters. Inquiries should always be instituted as to the *permanence* of a source of water-supply; analyses should, if possible, be made at two or three different periods in the year, and if one only can be made, the season and its probable effect upon the water should be considered and allowed for.

At sea and in coast towns where the rainfall is scanty and precarious (as at Aden), DISTILLED WATER is often used.†

* From VIth Report of Rivers' Pollution Commissioners.

† *E.g.* In the late Egyptian campaign enormous quantities of water for

Now-a-days nearly every vessel carries apparatus for the distillation of sea water* or for condensing steam from its engine-boilers; but in case of failure of fresh water on board a ship any means of heating salt water and condensing the vapor will afford a supply. The steam may be collected on a metallic surface, or on an earthen dish, changed when it becomes heated; or may be received in a clean woollen cloth, wrung out from time to time as it becomes saturated. Water thus obtained is insipid and perhaps indigestible, owing to absence of aëration. This disadvantage is obviated by exposing it to air in divided streams. It may contain sodium chloride, but not to any considerable degree. Magnesium chloride volatilized and decomposed may contribute hydrochloric acid, which should be neutralized by a little sodium carbonate.

DISEASES PRODUCED BY DRINKING IMPURE WATER.

The question of the production of disease by the use of impure water is one of surpassing interest in this country but space does not permit more than a summary of the present state of our knowledge in this matter. Suspended Inorganic (mineral) Impurities in excess may produce diarrhœa. Dissolved Inorganic (mineral) Impurities in excess, as in the case of waters with a high degree of permanent hardness, may cause dyspepsia and chronic constipation or in other cases, *e.g.*, where large quantities of magnesium sulphate are present, diarrhœa and intestinal irritation, thus weakening the intestines and predisposing to cholera or enteric fever.

The effects of Dissolved Organic Impurities are not supposed to be so formidable as those of Suspended, the latter including such diseases as are propagated by means of organized germs or spores, the former those due to

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the use of the troops on shore were distilled daily from sea-water by steamers fitted with powerful condensing apparatus.

* Zinc must not be used in any part of the condensing apparatus on account of the lead it generally contains; so also red lead is objectionable. In the best forms of such apparatus (Normanbys') the water is aërated artificially before distribution.

irritant poisons. Of the two classes of dissolved impurities of organic origin, the vegetable are certainly the less hurtful; indeed it is doubtful whether any ill-effects can be traced to them. Putrescent animal matters, on the other hand, especially those arising from fæcal contamination, are often productive of serious consequences. The intestinal tract is most liable to disturbance, and diarrhœa and dysentery are not unfrequently due to this cause. The composition of the poison producing these results is not known; and it has often been observed that water abounding in organic matter, having been drunk for months or even years with impunity, has suddenly developed poisonous material. In some cases this may be due to unsuspected communication with a foul drain or cess-pool, suddenly established or enlarged: in others, unusual elevation of temperature may have concentrated the water or set up putrefactive changes or may have favored the formation of the fatty acids which are known even in minute amount to be highly irritating to the bowels. Epidemics of dysentery or diarrhœa recurring annually in the hot season are probably attributable to one or other of these effects of heat upon drinking water. Diarrhœa may, in general, be expected if the water contains from 5 to 15 milligrams of putrescent animal organic matter per litre (parts per 1000,000), although larger amounts may be present in clear and sparkling water without apparent ill-effect, until the obscure putrefactive or fermentative changes mentioned above take place.* No doubt, other impurities are also present, and it is not possible to allocate definitely the share which animal organic impurity contributes to the production of intestinal irritation; but it may be laid down that the use of water containing this ingredient should never be permitted and that water contaminated by percolation through burial-grounds is the most noxious.

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* A case is reported in the *Lancet* of April 29th, 1871, in which an epidemic of diarrhœa in a girls' school is attributed to the use for *washing* of water which had stood for two years in a cask.

How far Specific Diseases, as enteric fever and cholera, are dependent upon *dissolved* organic impurities cannot be stated. It is known that the former is propagated by water polluted with fæcal impurities, and that a large proportion of those who drink water containing the specific typhoid poison are attacked by the disease : but whether this poison is a possible product of fæcal sewage simply, or necessarily of sewage including the evacuations of enteric-fever patients, is still an undecided question. It is stated that propagation by water is less common than by air but that the period of incubation is shorter, a large quantity of the poison obtaining entrance to the system and coming more immediately into contact with the intestinal tract. It may be that the specific means by which this disease is communicated is not a dissolved animal poison, but a suspended organized germ ; and in this case putrescent animal products would favor its spread by exciting non-specific diarrhœa and acting as a pre-disposing cause. The same remark applies to cholera. Diarrhœa resulting from the use of water holding animal matters in solution is said to increase the susceptibility to the specific cholera-poison or cholera-germ. Either directly or indirectly, therefore, water thus polluted favors the spread of these specific diseases. It may be added that the diarrhœa resulting from water containing a large amount of putrescent animal matter is frequently choleraic in type and in severity.

As regards malaria and its possible communication by drinking water there is still no certainty either way.

It is probable that vesical calculi are especially common in districts where hard water is drunk.

The causation of goitre is still doubtful but a common idea and, it is believed, a correct one is that the occurrence of this disease is intimately associated with the constant use of water derived from limestone or dolomite ($CaCO_3$ $MgCO_3$) rocks.*

* Goitre is extremely common in Kashmir and the Chin country, either

A large number of animal parasites (with the diseases resulting therefrom) find entrance to the human body by means of impure drinking water.* In some cases the ova pass directly into the alimentary canal, in other cases there is an intermediate host. Severe bleeding from the mucous surfaces of the mouth and throat has been caused by small leeches (*Sanguisuga sp.*) taken in with the drinking water in Algiers and Minorca : it is probable that this also occurs sometimes in India and Burmah. The following are the principal known parasites which find entrance by means of impure drinking water. Some of them are conveyed to the human body more usually by other sources, *e.g.*, food, but impure water is almost certainly one vechicle of infection in the case of all the parasites mentioned.

Tœnia Solium (?)—the common tape worm of man derived fr m eating measly pork. It is possible that pigs get infected by drinking water fouled by human excreta containing the ova.†

Tœnia mediocanellata—the tape worm of man derived from eating measly beef. The cattle derive the ova from water fouled by infected human excreta.†

Bothriocephalus Sp. (?)—probably from fish which have lived in water into which the ova of this tape worm have originally been discharged.‡

Distoma Hepaticum—the liver fluke commonly found in sheep, occasionally in man; intermediate host a small fresh water mollusc.

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of which districts, but especially the latter, from the absence of many disturbing factors, offers excellent material for research in this matter. The disease seems chiefly confined to women, but one sometimes sees male Chins with goitre, and at least one sepoy in the old 38th Regt., B. I. became affected. (*v.* also Neve I. Med. Record, Vol. III, p. 332).

* The subject is by no means worked out in India either as regards human beings or other animals. Tank waters swarm with nematoid worms and other organisms of which the life-history and *raison d'être* are but little understood. For further details of life-history, etc., *v.* the works of Leuckhart, Cobbold, etc.

† The common food of pigs and cattle in many Indian towns during drought is simply dried human ordure.

‡ *v.* Moore, Diseases of India, 2nd ed., p. 556.

Ascaris Lumbricoides—the round worm, extremely common throughout India and the tropics generally.

Anchylostomum Duodenale—produces the disease known as anchylostomiasis in Assam and in various other parts of India.*

Filaria Dracunculus—or guinea worm, formerly supposed to obtain entrance to the human body during bathing. Intermediate host is a cyclops, a small fresh water crustacean abounding in Indian tanks. The introduction of pure drinking water has caused its disappearance in various parts of India, *e.g.*, Perambur (in Madras).

Filaria Sanguinis Hominis—the embryo of which is abstracted by the mosquito from the blood of infected persons, whence, after undergoing certain developmental changes, it is deposited in water and is probably taken directly into the alimentary canal of man along with the water drunk.

Bilharzia Hæmatobia (?)

Tricocephalus Dispar—the common whip worm.

General conclusions†—1. An endemic of diarrhœa, in a community, is almost always owing either to impure air, impure water, or bad food. If it affects a number of persons suddenly, it is probably owing to one of the two latter causes : and if it extends over many families, almost certainly to water. But as the cause of impurity may be transient, it is not easy to find experimental proof.—2. Diarrhœa or dysentery constantly affecting a community, or returning periodically at certain times of the year, is far more likely to be produced by bad water than by any other cause. —3. A very sudden and localised outbreak of either enteric fever or cholera is almost certainly owing to introduction

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* Sometimes called also *beri-beri*, but must be carefully distinguished from the true form of that disease with which it has nothing in common beyond the fact that the patient becomes anæmic in both diseases.

† From Parkes—Notter, p. 81.

of the poison by water*—4. The same fact holds good in cases of malarial fever, and, especially if the cases are very grave, a possible introduction by water should be carefully inquired into—5. The introduction of the ova (or embryos) of certain entozoa by means of water is proved in some cases—is probable in others—6. Although it is not at present possible to assign to every impurity in water its exact share in the production of disease, or to prove the precise influence on the public health of water which is not extremely impure, it appears certain that the health of a community always improves when an abundant and pure water supply is given; and, apart from the actual evidence, we are entitled to conclude from other considerations, that abundant and good water is a prime sanitary necessity.

PURIFICATION OF WATER—FILTRATION.

The purification of water by subsidence of the suspended matters, by filtration through the soil and by exposure to various oxidising media is constantly going on in nature, but almost as constantly, in the case of surface waters at least, fresh impurities are being added. It is necessary, accordingly, in many cases to purify a water artificially before use. One of the four following plans may be adopted, separately or combined with one or more of the others, *viz*:—

1. *Distillation*; 2. *Precipitation*; 3. *Boiling*; 4. *Filtration*. The first method has already been described.†

Precipitation is either *natural* or *artificial*. By the first method the suspended matters are simply allowed to sink to the bottom, as in 'settling tanks:'‡ by the second some substance is added which by means of the formation of a bulky precipitate carries down the impurities in its meshes. Such substances are very numerous. *a*. Alum, especially if calcium carbonate is present, acts very well. Calcium sulphate is formed and a bulky precipitate of aluminium hydrate. Six grains of alum to a gallon of water is a good

* It may be, in the form of ice. † *v*. p. 81. ‡ *v*. p. 52.

proportion. *b*. Lime, if added, combines with the CO_2 and thus causes the precipitation of the $CaCO_3$ already present. *c*. Potassium permanganate; impurities are oxidised, especially if the water is slightly warm, and in addition a precipitate of manganic oxide is sometimes formed which acts mechanically. A good plan is to add the permanganate first and then alum, or else filter the water. *d*. Iron; either as scrap iron or spongy iron* (with agitation of the water)†, or as the perchloride (about 2½ grs. per gallon). In both cases oxidation and precipitation take place. *e*. The 'Anti-calcare' of Maignen consisting chiefly of lime, alum and carbonate of soda. The carbonate of soda acts on lime and magnesia. *f*. Certain Vegetable matters, especially those containing tannin, *e.g.* tea,‡ kino, etc., and in India the fruit of the *Strychnos Potatorum* which swells up and forms a gelatinous precipitate, its action being purely mechanical.

Boiling is a most useful method for the purification of water either alone or as a preliminary. Long continued boiling destroys all living organisms; in addition any temporary hardness is precipitated and suspended impurities partly got rid of.

To sum up then impurities are most readily removed thus§ (exclusive of filtration):

Organic matter by	Distillation, boiling, exposure to air, alum, permanganates, tannin, and by agitation with iron, etc.
Carbonate of lime by	Boiling, or addition of caustic lime.
Iron by	Boiling, lime, and in part by charcoal.

* *v*. Bischof's filter, pp. 92—3. † *v*. p. 90.

‡ In a strange country it is an excellent rule never to drink water save in the form of tea, unless it has passed through an efficient filter. The action of the tea is threefold:—(1) The water is boiled (should be well boiled in this case). (2) The leaves form a mechanical strainer. (3) The tannin forms insoluble tannates.

§ Allan, *op. cit.*, p. 26.

The effects of FILTRATION are threefold. Suspended matters are retained in the interstices of the porous material of which filters are composed; dissolved inorganic matter is similarly, though to a less extent, separated; and oxidizable organic matter, suspended or dissolved, is oxidized, either by oxygen stored in the filtering material or by such substances as alkaline permanganates added to it.

Artificial filtration is carried out on the large or small (domestic) scale, but the principal is exactly the same in both cases.

On the *large scale*, the water-supply of towns or extensive buildings is, after the subsidence of the coarser suspended impurities in settling reservoirs, admitted to filtering beds composed of sharp sand with underlying gravel increasing in coarseness towards the bottom. The bed will be three feet or more in thickness, somewhat more than a third being sand. The rate at which water passes through such a filter depends upon the pressure, and this upon the depth of the water in the bed, which is usually about two feet. In general the discharge may be estimated at 70 gallons in 24 hours for each square foot of filtering surface. Finely divided clay if present in considerable quantity* will pass through such a filter, but most suspended matters will be retained. The amount of dissolved mineral matters will be considerably diminished in proportion to the thickness of the layer of sand, which also promotes oxidation of organic impurities. Micro-organisms are effectually removed for a short time, by certain sands, but this power is lost in a few days. It must be remembered that the more efficient a filtering bed is, the more rapidly will its interstices become clogged and its power of purification lessened or destroyed; and especially that dissolved matters at first removed will, at a certain point, begin to be restored to the outflowing water. This should therefore be examined

* The turbid water of the Hooghly carries down so much fine clay at some seasons as to block and render useless the sand-filters.

from time to time, and the sand removed and cleaned when necessary. It follows that two filtering beds should always be provided, in order to admit of periodical cleansing. In some water-works a so-called Revolving Purifier is in use. It consists of numerous small cylinders rotating on a horizontal or inclined axis, each cylinder being filled with little angular pieces of iron* lying loose in the cylinder. The water passes slowly through the revolving cylinder and is "churned up" with the iron, which latter continues to offer a bright clean surface owing to the constant friction. Finally the water is filtered through sand to get rid of the coloration imparted by the iron. In yet other cases the 'magnetic carbide' of iron* or Bischof's 'spongy' iron* are used, the water being previously passed through settling tanks and rough sand filters.

For the filtration of water on the *small scale* a great many substances have been used but of these only a few are trustworthy. *Organic filtering media such as sponge, cotton wool or flannel should never be used:* any advertised filter containing them should be rejected. Porous sand-stone filters in the form of jars are largely used by travellers in this country: by them turbid water is rendered clear and of pleasant appearance but their action on dissolved matters is practically *nil*. As a material for the preliminary straining of suspended impurities nothing is equal to closely-woven asbestos cloth. This mineral, as is well known, is unaffected by ordinary heat and the cloth can therefore be purified by washing it and heating it in a fire, by which means all impurities in its meshes can be got rid of. Of filtering media proper there are only two worth considering, *viz.*, *Charcoal* and *Iron*. They may be used separately or in the form of compounds produced by heating them together.

CHARCOAL is derived from the destructive distillation of organic matter either animal—bones, etc., or vegetable—wood,

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* *v.* Iron, p. 92.

peat, sea-weed, etc. Coke, derived as it is from the same process applied to coal (*i.e.*, mineralised vegetable matter), may be looked upon as mineral charcoal. All of these, if the layer is sufficiently deep, remove suspended matter from water filtered through them so that the latter passes out clear and sparkling. As regards suspended organic impurities animal charcoal exerts the most powerful influence on dead organic matter but is much inferior to vegetable or mineral charcoal in preventing the passage of micro-organisms. Fresh animal charcoal entirely oxidises dissolved organic matter and removes also dissolved mineral matters, especially lead. But it soon loses its power, more especially as regards the oxidation of dissolved organic impurities.

The conclusions to be arrived at with regard to charcoal as a filtering medium are these* :—" (1) It acts both chemically and mechanically, and is at first both rapid and efficient. (2) With a good bulk of material, water may be passed through nearly as rapidly as it can flow, and be well purified. (3) Water must not be left in contact with the charcoal longer than is necessary for filtration, as it is apt to take up organic matter again. (4) Water filtered through charcoal must not be stored for any time, but must be used immediately, as if kept it is apt to become charged with minute organisms. (5) Since fresh organic matter may pass through it unchanged, animal charcoal cannot be confidently depended upon to purify water from disease poison. (6) The power of charcoal is limited; with a moderately good water it remains efficient for some time, but with an impure water it soon becomes inactive. In all cases it ought to be cleaned or renewed at least every three months, and with impure waters much oftener, say, every week or every fortnight." Having regard to No. 5 it might be advisable in a charcoal filter to have two layers, one of animal and the other of vegetable or mineral charcoal. When charcoal is used it must be pounded and

* Parkes—Notter, pp. 86—7.

compressed so as to retain the water for about four minutes in its passage through the filtering medium.

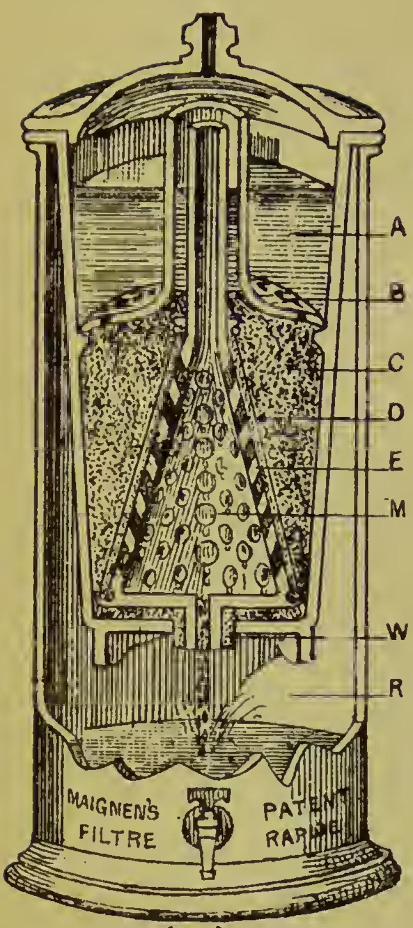
Iron as a filtering material is chiefly used in the form of so-called spongy iron (Bischof's) which is obtained by roasting hæmatite iron ore. It consists chiefly of porous metallic iron. As a filtering medium it ranks very high, its action being both mechanical and chemical. It arrests suspended matter and micro-organisms, oxidises dissolved organic matter and removes lead. Upon dissolved mineral matters it does not have much effect. In all cases its action is slow but water that has been filtered through it does not become deteriorated for a long time.* Besides these there are numerous other materials that have been used from time to time of which the important ones are nearly all compounds of iron (or manganese) and charcoal. Such are magnetic carbide, manganous carbon, carbalite used in Crease's filters in the Royal Navy, polarite or magnetic spongy carbon much used at the present time both on the large and small scale, etc.

A somewhat new idea is the filter known as the Pasteur-Chamberland, where the medium is simply a cylinder of porcelain through the pores of which the water passes under pressure direct from the tap. It effectually removes suspended matters and micro-organisms but has little action except when perfectly new, on dissolved organic matter. The latest filter is the Berkefeld made somewhat after the pattern of the foregoing, but in this latter case the cylinder is made of diatomaceous earth, *i.e.*, of innumerable siliceous 'skeletons' of fossil *diatoms* which form an open or porous structure, the meshes being extremely minute. It is said to possess the following advantages:—(1) It will filter large or small quantities according to pressure; (2) the filtered liquid will be absolutely free from any solid particles and from germs; (3) the filter can be easily cleaned; (4) each filter can be thoroughly sterilised by being boiled in water for an hour, and, moreover, one cylinder will last for years.

* *Cf.* Charcoal, p. 91 (4).

PLATE IV

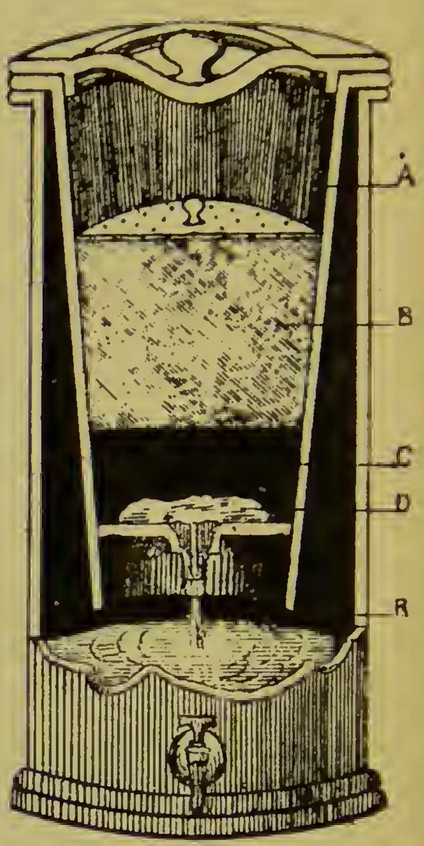
I



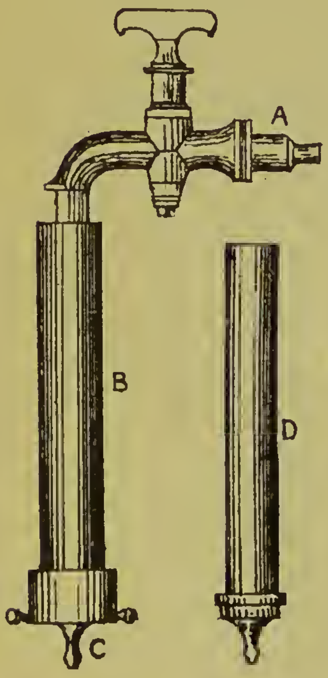
(a.)

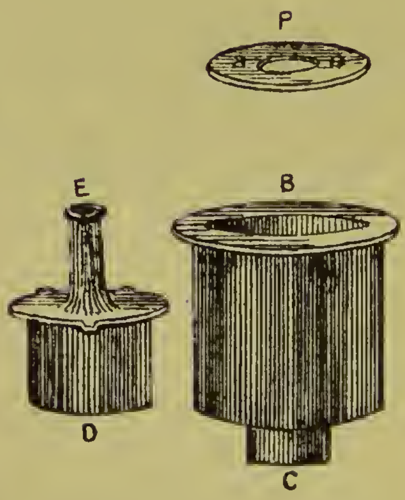
(b.)

II.

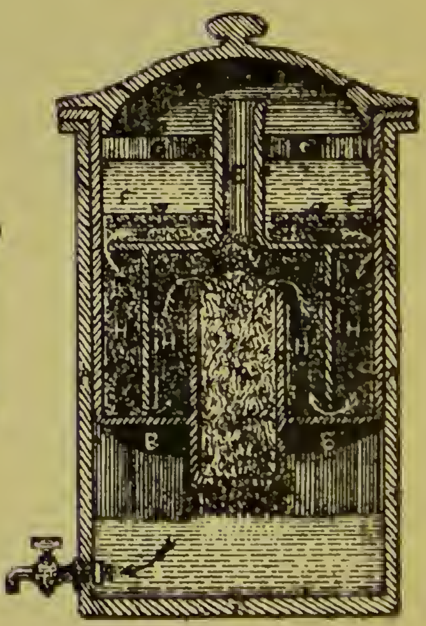


IV





III



LITH. BY ROSS, BROS.

To face p. 92.

PLATE IV.

DOMESTIC FILTERS.

I. (*a*) Filtre Rapide (Maignen), in section. A. Filter case proper; R. Reservoir for the filtered water; M. Filtering frame secured within the case by pure asbestos washer (W); E. Asbestos cloth attached to filtering frame with asbestos cords; D. Layer of *powdered* Carbo-Calcis; C. Layer of *granular* Carbo-Calcis put in loosely to fill space between (D) and the screen (B).

(*b*) Shows method of cleansing the filter by removing the frame (M) and washing away the used Carbo-Calcis.

II. Spongy Iron Filter (Bischof), in section. A. Filter case proper; R. Reservoir for the filtered water; B. Fine Spongy Iron; C. Pyrolusite; D. Abestos cloth bag.

III. Circulating Filter (Morris). An ordinary outer case or vessel, A, is divided into two parts by the division, B, which forms part of a separate vessel dropped into the outer case and hanging by a broad rim. In the centre, and forming part of the division B, is a tube, or chamber, C, the lower portion of which protrudes an inch or two, so as to form—with the aid of the capillary attraction of the material—a siphon arrangement, whereby the filter is drained perfectly dry at each operation.

The lower end, or outlet, of the vessel C, is provided with a strainer of fine holes, the upper mouth, or inlet, being left open. Into this containing vessel, and over the tube C, is loosely placed a second circular tube or chamber, D, with its mouth downwards. This vessel is made to stand higher than the central tube, C, and is also of much larger diameter, so that the interior space of the filter is partitioned vertically at regular distances by the chambers C and D. The upper part of D forms a flat plate, having an open air tube, E, rising from the centre, and the diameter of this flat plate being a little less than that of the containing vessel, leaves an annular space or clearance around it of about ¼ in. at F. Water poured into the upper part, G, of the filter, and around E, must therefore find its way through the annular space at F, down one section of filtering material under the chamber D, up through another section of material till it flows over the top of chamber C, and so down through a third column of medium and through the strainer into the lower compartment of the filter. If now the filtering medium in the central tube or chamber C, be coarse and porous as at J, and that in the spaces H and H′ of a very fine and close nature, it follows that the water will percolate very slowly down the space H and up the intermediate section H′, but will rapidly escape down the central tube or chamber C, and instead of accumulating and flooding the interior of the filter, it trickles down from particle to particle of porous carbon—highly

charged with air—thus leaving the mass of material in a semi-dry state, and allowing a supply of fresh air to penetrate down the air tube E, into the very centre of the filter. The action is therefore automatic, the flow of water drawing a current of air down into the carbon, which absorbs it, but gives it up again to the water as it percolates down the central tube. [NOTE.—The letters are, unfortunately, not very clear in the plate, but, if the above description be carefully followed, the action of the filter can be easily understood].

IV. Pasteur-Chamberland Filter. A. Water-tap attached, at A, to water-pipe; B. Outer case of filter; C. Mouthpiece; D. Porcelain Cylinder or 'Candle' (*v.* also fig. 1, pl. v.)

It is believed that one of these two latter filters is to replace the Macnamara filters at present in use in barracks, hospitals, etc., in this country.*

The essentials of a good filter are the following :—

"(1) That every part of the filter shall be easily got at for the purpose of cleaning or of renewing the medium. (2) That the medium have a sufficient purifying power both as to chemical action on organic matter in solution and arrest of organisms or their spores in suspension, and be present in sufficient quantity. (3) That the medium yield nothing to the water that may favour the growth of low forms of life. (4) That the purfying power be reasonably lasting. (5) That there shall be nothing in the construction of the filter itself that shall be capable of undergoing putrefaction or of yielding metallic or other impurities to the water. (6) That the filtering materials shall not be liable to clog and that the delivery of the water shall be reasonably rapid."†

Filters for ordinary domestic use are sold in very many shapes and sizes, but the number of really good ones as judged by the foregoing standard is very small. They are roughly divisible into classes according to the material used for filtering as follows‡ :—

(1) Those containing animal charcoal in granules or powder. (2) Animal charcoal compressed into blocks by admixture with silica and other substances. (3) Spongy iron filters. (4) Magnetic iron filters. (5) Cylinders of porous inorganic material such as porcelain. (6) Those containing other substances of varying nature, chiefly mineral. Three of the best known, and most efficient patterns are the Filtre Rapide (Maignen's), the Morris Circulating Filter

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* "The sterilisation of fluids by mere and comparatively rapid filtration must be regarded as a distinct and important advance in bacteriological Science." *Lancet*, 12th September 1891 : *v.* also Sanitary Record, 15th November 1892.

† *v.* Parkes—Notter, p. 89, for further information.

‡ *Ibid. loc. cit.*—altered.

and the Spongy Iron Filter (Bischof's). To these must be added the Pasteur-Chamberland and Berkefeld as described above. The construction and working of these various forms are sufficiently explained in the diagrams.

In India a favourite form is the filter made of three *chatties* or *gharrahs* on a bamboo stand. The uppermost is half filled with pounded charcoal, the middle one with fine sand* and a layer of small stones underneath: both are perforated with small holes in the bottom. The lowest chatty contains the filtered water. It is a good filter *if very carefully looked after.* The filtering media must be as clean as possible in the first instance and any surplus must be stored in clean chatties or boxes. The charcoal should be renewed every fortnight or once a week if the water is very foul; the sand and stones should be taken out, cleaned and dried once a month, also the chatties themselves. Two filters may be kept so that one can always be cleaned when necessary. The chatties should also have removable perforated lids and the lowest one should be renewed when it loses its porousness. The holes should not be quite at the lowest portion nor too large, otherwise the water is apt to run straight through without proper purification. The daily filling of the filter must be superintended by some responsible person; if not, the waterman or bhisti will be certain to pour the water straight into the lowest chatty to save time and trouble.

For large institutions such as barracks, asylums, ships, etc., various special types of filters are in use but they are either imitations on a small scale of the larger sand filters, or else the same in principle as the filters described. One type of filter however, *viz.*, the Macnamara, deserves special mention as it is the filter officially supplied to Military hospitals, barracks, etc., throughout India.† It consists of a stout cylindrical zinc vessel closed at the upper end

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* Both the charcoal and the sand should be well pressed down.
† *v.* I. A. R., Vol. VI., Medical, Madras, 1885.

excepting where the delivery pipe is attached, whilst below it fits into a tray containing a perforated earthenware disc. The interior of the vessel is divided into compartments by removable perforated zinc trays and is so charged with filtering materials that at the top there is a little coarse sand, below this a deep layer of coarse and fine animal charcoal, below this is fine sand and finally coarse sand resting upon the perforated earthenware disc. When ready, the filter is placed in a three-quarter cask the inner surface of which is charred, and the delivery pipe connected with the tap attached to the latter. The cask is then filled with water, the lid fastened down, and upward filtration takes place. The arrangement and working of the filter can be understood from the accompanying diagrams, it being remembered that the filter is turned upside down during the process of charging.

No filter is self-cleansing though many are stated to be so. The proper management of the various forms of filter on a large scale requires a good deal of experience and technical knowledge. Domestic filters must be most carefully attended to or else they simply become the chief source of impurity to the water passed through them.

Charcoal is best cleaned, so to speak, by renewing it but if this cannot be done it should be heated to redness in the absence of air* if possible, and then washed with clean water; if this is not possible it should be boiled with permanganate of potash solution to which a little dilute hydrochloric acid has been added. *Sand* in large filters should be partially renewed frequently by scraping away the top layer and adding fresh clean sand and should be completely changed at longer intervals of six months or so. In small filters it may be renewed, or taken out, washed and then heated by baking or exposure to the sun and afterwards washed again with permanganate of potash solution. *Spongy iron* lasts for a long time—six months to a year—it

* By placing it in a perforated metal cylinder which is caused to revolve slowly over a fire.

should then be renewed if possible; if not, it must be heated to a low red heat and afterwards well washed with clean water only.*

When travelling in India and obliged to drink doubtful water, if no better means of purification is at hand, the water should be made into tea and drunk in that form only. Travellers, however, if unprovided with a good filter should always carry a small stoneware bottle-filter† and an ounce or two of permanganate of potash. First add a few grains of permanganate of potash and then heat gently; add more potash salt till the pink tinge remains for about ten minutes;‡ boil thoroughly, cool and shake well in some convenient vessel and then, after subsidence of the coarse suspended matters, filter through the stoneware filter. In this way a supply of drinkable water can be easily made and used till the next halting stage.§ It is just within the limits of possibility that Indian Railway Companies will some day provide really pure, cool water in abundance for all travellers.

EXAMINATION OF WATER.

The examination of water will only be considered very cursorily here, for it is a highly technical subject requiring a special training and a fully-equipped laboratory.

The Collection of Samples of Water.—This is a very important duty which may have to be performed by any medical officer. The following directions|| should be most carefully adhered to:—

Analysis of Water.—Before forwarding a sample of water

* In a filter where the medium is spongy iron, the latter must always be kept covered with water: in the newest form of Bischof's filter this is provided for.

† Obtainable all over India and Burmah.

‡ As judged by pouring a little of the water from time to time into a tumbler or clear glass bottle.

§ The small amount of trouble involved in the above process will be amply repaid by freedom from sickness and in many cases by one or more lives saved. If the Pasteur-Chamberland, Berkefeld or other types of pressure filter come into the Indian market, it is worth while remembering that very considerable pressure may be obtained by hanging the vessel containing the water high up in a tree or on the top of a house and connecting it by rubber tubing with the filter near the ground level.

|| *Extract from G.O.G., Madras, No. 1062, Public, dated 30th May 1883, Chemico-legal Examinations.*

to the Chemical Examiner for analysis, it is necessary to write to the Chemical Examiner and ascertain when it will be convenient to receive the sample or samples which may require to be examined, it being desirable that samples should be examined shortly after they are received at the Laboratory.

(2) The duty of collecting the samples should always be undertaken by a responsible person. The employment of peons or servants for this purpose is strictly prohibited. The bottles used should be thoroughly cleansed, and then well washed out twice with water from the same source it is intended to fill them from, just before finally filling them.

(3) Glass stoppered bottles are best, but if those are not procurable, new corks are to be used with the ordinary quart wine bottle of light colored glass. In filling the bottles a little space should be left between the cork and the water. [The mouth of the bottle should be plunged under the surface, but should not touch the bottom.]

(4) Not less than one gallon of each sample of water is to be forwarded.

(5) Each bottle to be labelled, with the name of the well [or tank, etc.], and date of collection.

(6) On forwarding water for analysis, the Medical Officer should, at the same time, forward separately a letter to the Chemical Examiner. This letter should contain :—

(*a*) An impression and description of the seal used in closing the bottles.

(*b*) Information as to the number of samples sent, and a statement as to how the samples have been forwarded. [By hand, rail, steamer, etc.]

(*c*) An explanation as to the reason for which the examination is required, and information as to by whom it is desired.

(*d*) A statement as to the source from which each sample was collected, and by whom and when each sample was collected.

The information given under 6 (*d*) should be as full and complete as possible, having reference to the geological and meteorological conditions of the place, distance of the well, etc., from possible source of impurity, nature of the collecting surface, supposed connection with outbreak of any particular disease and any other information obtainable. If the water is very bad or if a very complete mineral analysis is desired, two gallons or more should be sent. For the bacteriological examination of a water special methods and precautions are necessary which it is unnecessary to detail here.*

In practice the examination of water for hygienic purposes admits of division into four degrees of accuracy.

I. The very rough and speedy examination which has frequently to be made by a Medical Officer at the end of a long march or journey when many thirsty soldiers or other persons are waiting to be allowed to drink. There may be several sources to choose from—one or more wells or tanks, a shallow stream, the backwater of a large river, etc., etc. From what has been said before a good idea can be gathered as to which is likely to prove the best source of supply. After inspecting these rapidly the Medical Officer should examine samples of the water brought to him for that purpose by sight, taste and smell, remembering that in tasting a water it is unnecessary to swallow any of it.

II. *Physical examination.* This though requiring no chemicals, often gives valuable hints as to the impurity or otherwise of a water and can be made by any educated person when there is a little time to spare, *e. g.*, in choosing the site of a temporary camp which is to be occupied a day

* *v.* Manl. Pratique D'Analyse Bacteriologique des Eaux, Le Dr. Miquel, Chapitre I, Paris, 1891.

or two later. The points to be inquired into regarding the water are as follows :—

1. *Colour.*—This is best examined by pouring some of the water into a tall cylindrical glass vessel one and a half to two feet in depth, which is then placed on clean white paper and the colour compared with a similar vessel filled with distilled water. If no distilled water is available the original vessel may be filled half full and the colour of the water compared with the column of air above it. This test must always be done in a good light. Distilled water is almost colourless ; pure waters have a faint bluish tinge. Green waters are very common in India, especially in tanks, the colour being due to minute fresh water algæ. Yellow or brown waters are so coloured by animal or vegetable organic matter or are chalybeate. If there is the remotest chance of the pollution being due to animal matter the water should be rejected, but in this country, save close to towns or villages, such colouration during the rainy season is generally due to vegetable matter.

2. *Clearness.*—Shake up the sample of water so as to divide the suspended matter equally and then pour some into the cylindrical vessel as before. Instead of the white paper put a piece of ordinary newspaper underneath and by gradually adding a little more of the sample ascertain the exact depth at which the printed matter becomes obscured. The latter can easily be read through 24-inches depth of distilled water.

3. *Taste.*—This is not a very reliable test, for though all good waters are practically tasteless and any water with a bad taste is at once rejected, the important fact remains that many of the worst waters are free from any disagreeable taste. If mineral matters are present in large extent the water will probably be objectionable in taste. A small amount of iron will do no harm in water for temporary use.

4. *Smell.*—If the water has a disagreeable smell it should be rejected. Warming the water gently or even boiling

sometimes brings out its peculiar smell, particularly if there is much animal impurity present. In some foul waters the presence of hydrogen sulphide is thus rendered perceptible.

5. *Sediment.*—This if present in large quantity can be approximately estimated by pouring the water into a narrow cylindrical vessel, *e.g.* a long test tube, and allowing it to settle. The naked eye alone or a small hand lens can often detect the presence of numerous animal and vegetable impurities, *e.g.*, crustaceans (*cyclops, daphne, etc.*), worms, algæ, larvæ, etc., but it should always be examined with a microscope if possible. If the number of animalcules and microbes is very great so that the field of the microscope swarms with them the water should be rejected.*

6. *The Lustre.*—The degree of "sparkle" in a water is sometimes recommended to be noted as indicating the amount of aëration but is of no practical value as some of the worst waters, *e.g.* from wells sunk in graveyards, have the most brilliant lustre.

If then on the one hand a water is deeply coloured, very turbid, bad tasting or strongly smelling it should be rejected as unfit for use, but if on the other hand it is colourless, clear, tasteless and odourless it may be accepted provisionally provided that more thorough means of analysis are not available.

III. *Qualitative examination.*—This can be carried out in any station or institution where the ordinary chemical reagents are available and indications of considerable value may be thus obtained. The physical and microscopical examination should first be carefully carried out and if the water is not condemned by these tests the chemical examination may be proceeded with. The following table shows the various tests clearly.†

* The number of objects, both animate and inanimate, that may be found in water by microscopic examination is so great that it is impossible to give any adequate description of them within the limits of this manual. In addition, the recognition of each form and the probable value attachable to its presence, needs special training and experience not to be gained from any book.

† Taken by permission of the author and proprietors (Messrs. Churchill) from Parkes-Notter *op. cit.*, p. 686 *et seq.*

QUALITATIVE EXAMINATION OF DISSOLVED SOLIDS.

The water may be either at once treated, or, in the case of some constituents, it should be concentrated by evaporation.

Water not Concentrated.

Substance sought for.	Reagents to be used, and effects.	Remarks.
Reaction	*Litmus* and *turmeric* papers; usual red or brown reactions.	Usually neutral. If acid, and acidity disappears on boiling, it is due to carbonic acid. If alkaline and alkalinity disappears on boiling, to ammonia (rare). If permanently alkaline, to sodium carbonate.
Lime	*Oxalate of ammonium.* White precipitate.	Six grains per gallon (9 per 100,000) give turbidity; sixteen grains (23 per 100,000) considerable precipitate.
Chlorine	*Nitrate of silver*, and *dilute nitric acid.* White precipitate becoming lead colour.	One grain per gallon (1·4 per 100,000) gives a haze; four grains per gallon (6 per 100,000) give a marked turbidity; ten grains (14 per 100,000) a considerable precipitate.
Sulphuric Acid	*Chloride of barium* and *dilute hydrochloric acid.* White precipitate.	One-and-half grains (2 per 100,000) of sulphate give no precipitate until after standing; three grains (4 per 100,000) give an immediate haze, and, after a time, a slight precipitate.
Nitric Acid	*Brucine* solution and *pure sulphuric acid.* A pink and yellow zone.	The sulphuric acid should be poured gently down to form a layer under the mixed water and brucine solution; half a grain of nitric acid per gallon (=0·7 per 100,000) gives a marked pink and yellow zone; or, as recommended by Nicholson, 2 c. c. of the water may be evaporated to dryness; a drop of pure sulphuric acid and a minute crystal of brucine be dropped in; 0·01 grain per gallon (=0·0143 per 100,000) can be easily detected.
Nitrous Acid	*Iodide of potassium* and *starch* in solution and *dilute sulphuric acid.* An immediate blue colour.	Add the solution of iodide of potassium and starch, and then the acid; the blue colour should be immediate; make a comparative experiment with distilled water.

Substance sought for.	Reagents to be used, and effects.	Remarks.
	Solution of *metaphenylenediamine* and *dilute sulphuric acid* (Griess's test)—a yellow colour more or less immediate according to amount of nitrous acid.	This is a very delicate test; a yellow colour will appear in the water in half an hour, if there be only one part of nitrous acid in 10,000,000 of water.
Ammonia	*Nessler's* solution. A yellow colour or a yellow brown precipitate.	If in small quantity, several inches in depth of water should be looked down through on a white ground.
Iron	*Red* and *yellow prussiates of potash*, and *dilute HCl*. Blue colour.	The red for ferrous and the yellow for ferric salts.
Hydrogen Sulphide	A soluble salt of *lead*. Black precipitate.	When the water is heated the smell of hydrogen sulphide may be perceptible.
Alkaline Sulphides	*Nitroprusside of sodium*. A beautiful violet-purple colour.	A black precipitate with lead, but no colour with nitroprusside shows that the hydrogen sulphide is uncombined.
Oxidisable matter, including organic matter	*Gold chloride*. Colour varying from rose-pink through violet to olive; a dark violet to black precipitate.	The water, which should be neutral or feebly acid, must be boiled for 20 minutes with the gold chloride. If no nitrous acid be present, the reaction may generally be considered due to organic matter.
Do.	Note the darkening of the *silver chloride* in testing for chlorine.	Compare with a precipitate produced in a pure solution of a chloride.
Lead or Copper*	*Ammonium sulphide*. Dark colour, not cleared up by hydrochloric acid.	Place some water (100 c. c.) in a white dish, and stir up with a rod dipped in ammonium sulphide; wait till colour produced, then add a drop or two of hydrochloric acid. If the colour disappears, it is due to iron; if not, to lead or copper.†

* Sidney Harvey (*Analyst*, vol. vi. p. 146) recommends small crystals of potassium bichromate. According to him $\frac{1}{10}$ of a grain per gallon gives an immediate turbidity, $\frac{1}{20}$ after 15 minutes, and $\frac{1}{50}$ after 30 minutes. These numbers equal respectively 0·14, 0·07, and 0·03 per 100,000.

† Wanklyn.

Substances sought for.	Reagents to be used, and effects.	Remarks.
Zinc	*Hydrogen Sulphide.* A white precipitate. If zinc be in considerable quantity, it is generally present as bicarbonate, and gradually forms a film of carbonate on the surface of the water. This film may be collected and heated on platinum foil. If the residue remain yellow when hot and white on cooling, the presence of zinc is indicated. This reaction is very delicate.*	This test is not possible if there be iron present, should the water be alkaline. It forms, however, in perfectly neutral waters, but not in acid. A little acetate of sodium greatly aids this; or ammonium sulphide with an alkaline solution in excess; or acidulate water with hydrochloric acid and add potassium ferrocyanide; a white precipitate appears, pale greenish if there is iron in the hydrochloric acid.

Water Concentrated to $\frac{1}{50}$ (in a Porcelain Dish.)

Magnesia	*Oxalate of ammonium* to precipitate lime, then after filtration a few drops of *phosphate of sodium*, of *chloride of ammonium* and of *liq. ammoniæ*. A crystalline precipitate in 24 hours.	A precipitate forms in 24 hours, and is the triple phosphate either in the shape of prisms or in feathery crystals.
Phosphoric Acid	*Molybdate of ammonium* and *dilute nitric acid.* A well-marked yellow colour, and on standing a precipitate.	Add the nitric acid, and stir with a glass rod, then add twice the quantity of molybdate and boil.
Nitric Acid	*Brucine* test.	If the nitric acid is in small quantity, it may not be detected in the unconcentrated water.
Silicic Acid	Evaporate to dryness, moisten with *strong hydrochloric acid;* after standing, add boiling distilled	The residue may be weighed, and thus the silica determined quantitatively. A little clay or oxide of iron will be sometimes mixed with it.

* Frankland, *Water Analysis*, 1880, p. 44.

Substances sought for.	Reagents to be used, and effects.	Remarks.
	water; pour off fluid; dry, ignite; repeat the treatment with hydrochloric acid and water; dry, ignite again, and the residue is silica, or silicate of aluminium.	
Lead or Copper	As before.	If quantity be very small.
Arsenic	*Marsh's* or *Reinsch's* tests.	Water should be rendered alkaline with *sodium carbonate* before concentration, then acidulated with *hydrochloric acid.*
Zinc	Evaporate to dryness; treat residue with *caustic potash* or *ammonia*, filter and test filtrate with *hydrogen sulphide;* a white precipitate falls.	This is necessary if the quantity be small, or if iron be present. If a film of carbonate forms on concentration, it may be tested on platinum foil, as before described.

Chlorine is nearly always present but if in considerable quantity giving a marked turbidity or a distinct precipitate its presence is important. It is derived from soil containing chlorides of sodium and calcium, from sea-water, or from contamination by urine or liquid sewage. In the latter case some or all of the following substances will be present in excess, nitric and nitrous acids and ammonia, phosphoric acid, and, if the impurities are recent, oxidisable organic matter.—Ammonia should not be present in sufficient amount to give the Nessler reaction in the undistilled water.—If the phosphoric acid reaction is distinct it is highly probable that the water is contaminated with sewage.—Should it contain any metal other than iron or the alkaline and earthy metals it is unfit for use.—If the water is 'hard' lime will be present in large quantity; if hardness is 'temporary', as $CaCO_3$ which is precipitated by boiling, if 'permanent' as $CaSO_4$, $Ca\ Cl_2$, $Ca\ (NO_3)_2.4\ H_2O$, and

is not precipitated by boiling.—If there is an abundant precipitate of magnesia in 24 hours, the water should be rejected. This is a common impurity in India.

IV. *Complete Quantitative examination.*—This really means the accurate determination of the quantity of each basic and acid radical and in addition the quantitative examination of—1. *The dissolved solids*—(*a*) *total* (*b*) *fixed* and (*c*) *volatile.* 2. *The hardness*—(*a*) *total* (*b*) *fixed* (*c*) *removable.* 3. *The free or 'saline' ammonia* and the nitrogenous organic matter (reckoned as '*albuminoid' ammonia*). 4. *The oxidisable matter.* In practice the whole of the basic and acid radicals are rarely estimated. The following are the more important as will be understood from what has been said before. 1. Chlorine. 2. Nitrous and Nitric acids. 3. Phosphoric acid. 4. Sulphuric acid.

The only quantitative process that need be referred to here in detail is the *Estimation of the Hardness of a water.* The two bases *lime* and *magnesia* (as well as iron, baryta, alumina, etc., to a lesser degree) with *free acid* (which acts by dissipating a lather already formed and which in this country is only likely to be carbonic) are the causes of Hardness, and, therefore, this quality is a test of their presence and may be made a measure of their amount. Ordinary *soaps* are stearates (or oleates) either of potassium or sodium, soluble in pure water. When dissolved in water and the solution well shaken, a *lather*, or collection of more or less permanent bubbles, is formed. If salts of the alkaline-earth metals (including magnesium) or of iron, etc., are present, the alkaline stearates are decomposed and insoluble stearates are formed instead, appearing as a curdy scum and ultimately as a precipitate. These insoluble stearates are useless for cleansing purposes and so much soap as is thus decomposed is wasted. Hardness, therefore, is a quality of great importance, economically in the first place and sanitarily in the second, inasmuch as any cause which renders cleanliness of clothes, dwellings and persons more expensive and more difficult of attainment is

necessarily detrimental to health. Further, as on the addition of an alkaline stearate to water none will remain in solution, and consequently no lather will be possible, until the whole of the calcium, magnesium and iron salts have (in the absence of free acid) been converted into stearates, the quantity of soap which has to be added to a given quantity of water in order to produce a lather is a measure of the amount of calcium, magnesium and iron salts in solution; in other words, of the hardness of the water. The quantity of soap required is ascertained by using a standard soap solution.

A standard solution of barium nitrate* is first required. This was formerly made of such a strength that it contained an amount of barium nitrate equivalent to 16 grs. calcium carbonate in 1 gallon of distilled water—or, as it was called, 16° of hardness on Clark's Scale† (in which therefore, each 1°=1 gr. $CaCO_3$ per gallon of water.)

It is more in accordance, however with modern methods to express the hardness, in common with other quantities, in Milligrammes per 100 cubic centimetres,‡ *i.e.*, parts per 100,000. Accordingly, a solution of barium nitrate containing 0·26 grms. $Ba(NO_3)_2$ in 1 litre of distilled water is made, so that each 1 c. c. of the solution contains 0·26 mgms. $Ba(NO_3)_2$§. Next, a solution of soap|| is made and tested or 'standardised' by the above solution, more of the soap or of the solvent being added, until 2·2 c. c. of this soap solution produce a permanent lather with 50 c. c. of the barium nitrate solution. Now, each cubic centimetre is divided into ten parts and these tenths are commonly called 'measures', *i.e.*, each 1 c. c. = 10 measures, or 2·2

* Or selenite (hydrated calcium sulphate) may be used; *v. gravimetric analysis* in glossary.

† From Dr. Clark of Aberdeen, inventor of the process v. p. 73.

‡ The so called *centesimal* scale.

§ 1 litre (1000 c. c.) water = 0·26 grm. $Ba(NO_3)_2$.
∴ 1 c. c. water = 0·00026 grm. $Ba(NO._3)_2$ = 0·26 mgm. $Ba(NO^3)_2$.

|| Undried Castile soap (said to contain 60 % olive oil) is the best: 25 grms. of this in 1 litre of weak alcohol will give a solution of almost the exact strength desired. If this cannot be obtained, ordinary B. P. soft soap may be used and standardised by the barium nitrate solution.

c. c. = 22 measures. From this 2 measures must be subtracted as necessary to give a lather even with the purest water. Hence, 2 c. c. or 20 measures are = (*i.e.*, give a permanent lather with) 50 c. c. of the standard barium nitrate solution. From this it follows that 1 c. c. of the soap solution is = 2·5 mgm. $CaCO_3$ and 1 measure is = 0·25 mgms. $CaCO_3$.* Knowing this, all that is necessary is to find out how many measures of soap solution are required to give a lather with a definite amount of the water to be tested and it becomes easy to calculate the amount of hardness, *expressed as calcium carbonate*, that is contained in the water.

The method of procedure is as follows :—

Into a stoppered bottle of about 200 c. c. capacity, which has been previously well rinsed with distilled water, are put 50 c. c. of the water to be examined. Next, a graduated burette is filled with soap solution. From this burette the soap solution is allowed to run slowly into the bottle, the latter being removed, stoppered and well shaken at intervals. When a lather begins to form on shaking, the bottle is laid upon its side and if at the end of five minutes a distinct frothy lather remains it is said to be 'permanent.' The experiment may require to be repeated two or three times with fresh 50 c. c. of water till the exact amount of soap solution necesssary is determined.† Sup-

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* Calculated as follows, by the *gravimetric* method (*v.* glossary): 20 measures of soap solution are required for 50 c.c. of the barium nitrate solution

$$\therefore \text{ 1 measure } \ldots \quad \ldots \quad \ldots = \frac{50 \times 0{\cdot}00026}{20} \text{ grm. } Ba(NO_3)_2.$$

Since the basicity of one molecule of $Ba(NO_3)_2$ = one of $CaCO_3$.
260 pts. by weight of $Ba(NO_3)_2$=100 pts. by weight of $CaCO_3$.
260 and 100 being the molecular weights of $Ba(NO_3)_2$ and $CaCO_3$ respectively.

$$\therefore 260 : 100 :: \frac{50 \times 0{\cdot}00026}{20} \text{ grm. } : x$$

$$x = 0\ 00025 \text{ grm.} = 0{\cdot}25 \text{ mgm. } CaCO_3.$$

† It is customary to make longer experiments with 50 c. c. of the water to ascertain the amount required approximately and then to repeat the process very carefully after adding *almost* the required amount at once. For further details *v.* Wanklyn's Water Analysis—Stevenson's and Murphy's Hygiene—Parkers-Notter, etc.

pose 13 measures are required. Then, substracting 2 measures as above-mentioned, 11 measures soap solution are = 50 c. c. of the water. But 1 measure is = 0·25 mgm. $CaCO_3$ and 50 c. c. of the water were taken, ∴ 11 × 0·25 × 2 = 5·5 mgm. $CaCO_3$ in 100 c. c. of the water and *i.e.* 5·5 parts {hardness in terms of $CaCO_3$} per 100,000 parts of the water. To express this result in Clark's Scale, multiply 5·5 by the short factor 0·7 = 3·85° hardness and *i.e.*, 3·85 grains calcium carbonate, *or its equivalent*, in 1 gallon of the water.

The foregoing, of course, gives the *total* hardness of the water. To find the *permanent* hardness, 250 c.c. of the water are taken and boiled over a naked flame for half-an-hour, the loss by evaporation being replaced from time to time by added distilled water so that there are always about 230 c. c. in the bottle. Then filter the water quickly into a graduated flask, washing the filter with a little boiling distilled water. When cold, add as much distilled water as is necessary to make up the amount to 250 c. c. exactly. Take 50 c. c. and titrate with the soap solution as before. Suppose 9 measures of soap solution are required. Then, subtracting 2 measures, proceed as before, *i.e.*, 7 × 0·25 × 2 = 3·5 mgms. permanent hardness expressed as $CaCO_3$ in 100 c. c. of the water. To find the *temporary* or *removable* hardness subtract 3·5, the permanent hardness, from 5·5 = 2 parts per 100,000 or on Clark's Scale (2 × 07)=1·4. The permanent hardness of a water should not be more than 5° of the centesimal (3·5° Clark's) Scale.* If magnesia is present in the water the amount of hardness *due to magnesia* may be roughly determined by a modification of the above process.†

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* Regarding the signification of the results obtained by the above process refer back to the impurities of drinking water. pp. 73-4.

† v. *opera cit. supra.*

CHAPTER III.

SOIL.

It is only of late years that systematic attention has been paid to the study of the ground or soil whereon we live in its relation to hygiene. To the Germans, especially von Pettenkoffer and his school, belongs the credit of initiating such systematic study. In this country, owing to want of encouragement and the absence of facilities, but little has been done by medical officers, save in the special case of Lewis and Cunningham at Calcutta.* The subject is one of extreme interest and importance and it is earnestly hoped that the Government will in future encourage its elucidation by all means in their power.†

Before proceeding to examine into the nature of the intimate connection that is believed to exist between the ground we live on and the occurrence of certain diseases, it is necessary to have a clear understanding as to what is really meant by this term 'soil.'‡ In the first place it is divided into the 'surface soil' and the 'sub-soil', terms which are merely relative and not exact. A perfectly pure soil would consist simply of certain mineral matters the result of the weathering or decay of the subjacent rocks. But, just as we find that in nature the air is something more than a mixture of oxygen and nitrogen and water something more than a compound of hydrogen and oxygen, so also the soil will be found to be a highly complex mixture. It consists then, from the point of view of a sanitarian,

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* *v.* Physiological and Pathological Researches, by the late Surgn.-Major T. Lewis (in concert with Surgn.-Major D. D. Cunningham, Calcutta.)

† *i.e.*, by *systematic* help and encouragement as opposed to the spasmodic appointment of 'Commissions.' It is a subject requiring *years* of study and observation and that not only in one city but in *many cities*. *v. post*, Ground air.

‡ Defined by Parkes as including, in this relation, "all that portion of the crust of the earth which by any property or condition can effect health."

of *mineral matters* of every possible variety, of *organic matter*—both animal and vegetable, living and dead—of *air* and of *water*.

The exact nature of the Mineral constituents does not concern us here save only as regards their general or chemico-physical properties, *e.g.*, the degree of aggregation of the particles, their power of absorbing heat, light or moisture, their solubility or the reverse, etc., all of which will be referred to again.

The Organic matter may be present in any amount from nearly *nil* to constituting the major part of the soil, and it may be of any nature and of any age from living protoplasm up to the stage of incipient mineralisation, as seen in some peaty deposits. The soil, in fact, may be looked upon as a vast underground laboratory in which, under the influence of an almost continuous network of vegetable roots, of myriads of animals,* and, most important of all, of countless micro-organisms, an unceasing series of chemical changes and reactions is for ever in progress. By means of these vital agencies the sub-soil is slowly but surely raised to the surface while the surface soil is as surely carried downwards. Yet again, in the neighbourhood of cities and even villages the influence of man himself is hardly less potent quantitatively whilst qualitatively its power for the production and spread of disease is far greater.

But in addition to the mineral and organic constituents we have the very important ones of Air and Water, by means of which these laboratory products as it were are diffused into the atmosphere or carried ultimately into the water-supply of communities. Not only, it must be remembered, do the various vital forms react upon and change the soil but in its turn the soil by its mineral and

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* *v. e.g.* Earthworms, by Darwin. The amount of soil that is annually turned over, raised to the surface and in various ways altered or exposed by burrowing animals, and by ants and other insects in India must be enormous. A study of this subject conducted experimentally on the same lines as Darwin's researches would well repay the trouble expended by a careful observer.

organic nutriment, its heat and its moisture, becomes the most favoured breeding ground of numerous animal and vegetable organisms, some harmless, some of great use and yet others of deadly potency.

The soil on which a house, tent or other dwelling is placed may influence the sanitary condition of the inhabitants, through the *climate*, through the *air* breathed and through the *water* used for domestic purposes. The circumstances which affect the *climate* of a place have reference principally to the chemico-physical properties of the soil and are respectively, (*a*) the conformation of the ground and its relation to the neighbourhood as regards position and elevation, (*b*) the vegetation which it supports, (*c*) the permeability of the soil and sub-soil by water, (*d*) their capacity for absorbing and their power of radiating heat, and (*e*) the color of the surface. Malarious or other miasmatic emanations may contaminate the *air*, and the *water* will be affected by the soluble substances, organic and inorganic, which it takes up in percolation through the soil.

LOCAL INFLUENCE OF SOIL ON CLIMATE.

Firstly then, must be considered the relation which the soil bears to the Climate of any locality.

Conformation.—Both the temperature and the humidity depend, to a great extent, on the conformation of the ground: including, if the place be uneven, the relative extents of high land and valleys; the degree of elevation of the highest parts; the forms, depth, width, slope, and nature of the sides of the valleys; the position and direction of the lines of drainage: and, if the level be uniform, the degree of slope and the capacity and direction of the water courses. Thus, as hills cool by nocturnal radiation more rapidly than lower land, a current of cold air will flow down a valley or ravine by night, depressing the temperature at the outlet. If the outlet be narrower than the main valley or ravine, so that the water draining from above has not sufficient means of escape, dampness will be added to coldness and alterna-

tions of temperature. As a rule, positions at the top of a slope will be found best; their temperature being lower and more uniform and free drainage preventing accumulation of water in the soil. As the conformation of the surface of a district is generally a consequence of its geological structure, a knowledge of the latter often affords an indication of the nature of the local climate and its probable effect on health. Thus good sites may be expected where granitic or metamorphic or trap rocks prevail; because these generally imply elevated positions, affording moderate temperature and free natural ventilation, as well as slopes favorable to drainage and consequent absence of excessive humidity. Deposits of clay, on the other hand, are generally flat, so that air stagnates and water lodges.

Relative Position.—Closely connected with the form of the ground itself is its Relative Position with respect to the neighbourhood. In a hilly country a site may be unhealthy, owing to its being so surrounded by hills that ventilation is impossible and the air is stagnant; and, as before observed, narrow valleys or ravines may become channels for currents of cold air, which chills at night a place so situated as to be exposed to its influence. A lower degree of the same cooling effect of elevated land may act beneficially when the more rapid radiation of heat from the latter produces a diffused cool breeze instead of a cold draught. On the other hand a low rocky hill, radiating at night the heat absorbed during the hours of sunshine, often renders places at its foot permanently hot and, if other causes combine, unhealthy.* A site, again, may be sheltered from the action of a prevailing wind by the intervention of a hill or range of hills—a circumstance which may be useful, as when the wind blows over a marsh, or injurious, as when a sea-breeze or other refreshing current of air is intercepted. This power of hills to shelter from, or alter the apparent direction of, the prevailing

* As seen very frequently in Central and Southern India.

wind should be borne in mind when we are choosing a site for temporary or permanent occupation.

Relative position has to be considered with reference to moisture also. A position at the foot of hills may suffer by excess of water flowing from them; either directly through humidity due to deficient drainage or indirectly through malaria produced by exuberant vegetation. In a plain itself a part depressed below the general level may be damp in consequence of the tendency of the drainage: and in this way soils which would under ordinary circumstances be dry and healthy (as gravels) may be in some instances damp and productive of disease.

Vegetation.—So far as the mere process of growth is concerned, Vegetation can be productive of good effects only: but exuberant growth involves excess of decomposing vegetable matter, which, under the influence of heat and moisture, is almost universally believed to be the source of malaria. On the whole, the good effects of vegetation exceed the bad. Herbage intercepts much of the solar heat and, by favoring gradual evaporation, cools and equalizes the temperature. Retaining a large proportion of the rainfall, it regulates the humidity of the atmosphere while, by preventing too rapid drainage, it helps to maintain the water-supply in the soil. Unirrigated crops act similarly, and neither they nor herbage are ever injurious to health. Shrubs and trees have the same effect upon temperature and humidity; but the former always, and the latter, especially the palms, during the earlier stages of their growth, are likely to obstruct seriously the free circulation of air. In the neighbourhood of dwellings, therefore, brushwood is objectionable and should be kept cut low or be altogether removed, while full-grown trees should have all their branches within 10 or 12 feet of the ground cut off; unless, as sometimes happens, a belt of trees shelters a site from a cold wind or intervenes between a place and a source of malaria. Finally, since the sanitary effect of herbage and of forest trees is almost

always good, the growth of the former should be encouraged to the utmost, and the latter should be planted judiciously in and about every inhabited place. In districts where the destruction of timber has raised the temperature and diminished the rainfall, the injury done to the climate and sanitary condition of the population should be repaired as far as possible by plantation.*

Permeability.—Almost all soils are permeable in some degree by water; but the power of absorbing and retaining it varies within wide limits, depending on the nature of the surface and of the soil itself. In considering Permeability the chief point, in relation to health, is the retention of water in excessive quantity by the soil; producing dampness of the air and reducing temperature in all cases, and generating malaria if the other conditions necessary to its production, heat and the presence of dead vegetable matter, are fulfilled. Such rocks, as *trap, granite, clay-slate* and the harder *limestones*, and *dolomites*, are practically impermeable and irretentive of moisture, not only in consequence of their structure, but because they generally present a slope which prevents the lodgment of water on their surface. On the other hand, *clays* are commonly flat, so that water lies upon them; and, though they are little more permeable than the harder rocks, saturation proceeds to the utmost. In some cases clays absorb and retain as much as 10 per cent. by weight of water. Through *sandstones, chalk,* and still more through loose *sand,* water passes readily and rapidly; but it must be remembered that the admixture of even a small proportion of clay impairs the permeability of sand and increases its retentiveness. *Humus,* or decaying woody fibre, absorbs and

* This is now being done in many parts of India by the Forestry Department and, in addition, forests already existing are protected from destruction by the ignorant. There is no surer way of ruining a district than reckless destruction of its forests and pollution of the sources of water supply, and, conversely, no one has a greater claim to the title of public benefactor than he who has changed a bare and barren land into a well-wooded country and given a clean and permanent supply of water in place of former scantiness and pollution.

retains from 40 to 50 times as much water as sand.* The old lacustrine deposits, commonly called *cotton soil,* are highly absorbent and retentive; and so also, though to a less degree, is the soil resulting from disintegrated granite, which yields much of our *red soil.* *Laterite* is permeable and irretentive, and *gravel* eminently so. Lastly, the roots of living *vegetation* impede the passage of water through a soil.

To apply these facts to the effects of permeability on health, it may be laid down, as a general rule, that the soils which are driest, whether because the water which falls on them runs off immediately or because it passes through them rapidly, are also healthiest. Where water lodges, on or in the ground, the air is damp and cold; and, as a consequence, there is a tendency to catarrhs and rheumatic affections, to phthisis and to malarious intoxication. Where the soil is dry the air also will generally be dry, the inhabitants will be free from those diseases and in other respects will be in better health. Hence, the hardest soils, from which the water runs off, and the most permeable, through which it passes rapidly, will (other things being equal) be the healthiest. A gravel hill or slope combines both these advantages. But there is an apparent exception to the rule that permeability of a soil implies healthiness. Gravel, for instance, may occupy a hollow either in hard rock or in clay, which holds the water in: so in this way a material naturally permeable may become saturated with moisture. It may be added that even a permeable soil, retaining water for but a short time, may generate malaria if organic matter be present.†

Heat absorbing power.—The nature of the surface and of theground beneath it determines the power of Absorbing

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* So much so that in Queensland, in seasons of drought, it is customary to cut down numbers of the "bottle-tree" which the cattle eat greedily on account of the moisture they contain.

† The sandy soil of the Deccan illustrates this latter exception. *v. post,* Malaria.

Heat, and in this way affects, either by conduction or radiation, the temperature of the place. The air immediately in contact with hot ground becomes heated, but rises and is replaced by a cooler stratum. The most absorbent soils, therefore, being the hottest, will be most productive of air-currents by conduction and convection. The best absorbents, again, are generally, but not always, the best radiators, giving out most rapidly the heat which they have received. During the day both processes are going on together; but in the evening, when solar heat is diminished, and at night when it is absent, radiation alone proceeds, and those soils which are most absorbent of heat cool most rapidly. In warm weather compact soils are on the average warmer than the loose; in winter, or on a fall of temperature in hot weather, colder. Also, in warm weather compact soils are warmer by day and colder by night than loose soils, and are subject to greater fluctuations of temperature.

The Material of which the soil is composed influences powerfully the degree of absorption and radiation. The following table shows the relative power of heat-absorption possessed by some ordinary soils :—

Sand, with lime	100·0
Pure sand	95·6
Light clay	76·9
Gypsum...	73·2
Heavy clay	71·1
Clayey earth	68·4
Pure clay	66·7
Fine chalk	61·8
Humus	49·0

It follows that in cooler climates clays and cultivated soils are cold; in warmer climates cool: on the other hand, that sandy soils are hot and, as will be seen, hotter in proportion to the darkness of their colour.

Two Ranges of Temperature are observable in soils—one

diurnal, the other annual.* The former extends to a depth varying with the solar heat and the nature of the ground, rarely more than four feet in temperate climates. According to Lewis and Cunningham† the temperature of the soil varies directly as the season so that during the hot weather the external air shows the highest temperature, then the upper layer of the soil, the deeper layers being coolest: in the cold weather these conditions are reversed. During the rainy season, again, their relations are naturally somewhat variable. The distance from the surface at which the temperature is uniform and equal to the mean annual temperature is said to range from 57 to 99 feet. Observations on these points in India are much needed.

The effects on health of varying absorptive power are referrable to those of temperature generally; the most absorbent soils being the most freely radiant. In estimating these effects, however, other things have to be considered besides degree of solar heat and radiant power of the soil. Aqueous vapour in the atmosphere absorbs the radiant heat, which through dry air would pass into space; and this again is radiated to dwellings and their inhabitants; so that aerial humidity also has to be taken into account. Water in the soil, again, being evaporated by the heat absorbed, retains much of the latter as latent. Thus marshy soils render latent most of the heat which they absorb: and in this way their poison is not unfrequently antagonized or neutralized by the cold which they themselves generate. In some malarious places the heat is radiated so quickly from the marshes at night that the temperature sinks to freezing point and the malarial poison either ceases to be evolved or is powerless to produce any ill effect. This probably happens in some places in the North West of India.

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* *cf.* the changes in the temperature of the sea, rivers, lakes, etc. *v.* Realm of Nature. H. R. Mill, p. 167, *et. seq.*

† *op. cit.*

Colour.—The colour of the surface affects the power of absorption of luminous, but not of obscure heat, the darker shades absorbing more heat than the lighter; but colour has no effect on radiation.

The colour of the surface may also be important in its result upon the sight. As blindness may be caused by the prolonged effect of snow, so the glare of white or of light-coloured ground may be disagreeable and even injurious in countries of bright sunshine. Green being the hue most refreshing to the sight, trees and grass are to be encouraged in places where quartz or other white rock occupies much of the surface; and buildings, instead of being whitewashed, should be coloured according to the materials available in the locality.

The Slope of the surface also, in relation to the sun's position during the hours of greatest heat, deserves consideration; reflection of heat rays being greatest and, therefore, absorption least, when the angle of incidence is greatest. Herbage is unfavorable to absorption and promotes coolness in this way, besides its action in cooling by evaporation and in converting solar heat into potential energy stored up in plants during the elaboration of the tissues and their contents.*

THE AIR IN THE SOIL—GROUND-AIR.

The air in the soil or the Ground-air varies in amount primarily according to the density of the soil. The very hardest rocks such as basalt contain no air, loose sand may contain 50 per cent. whilst between these are all possible variations in amount. Loose dry soil freshly ploughed such as we see commonly in this country may contain as much as ten times its own volume of air. The air itself is very impure being especially rich in carbonic acid and in organic effluvia of variable and generally unknown composition. In addition it may carry upwards with it,

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* *v. post.* Food, introductory.

as noted previously, numerous micro-organisms from their breeding ground in the soil. The degree of impurity of the ground-air, as measured by the amount of CO_2 present, depends upon many factors, the most important being the *composition* of the soil, its *heat, moisture* and *porosity* (which favours decomposition), and the *presence* or *absence of vegetation,* there being less CO_2 in the former case than in the latter. According to one observer* the amount of carbonic acid is greatest when the temperature is high, the moisture great and the diurnal variation in the temperature very slight.

The ground-air is not to be regarded as stationary or nearly so, on the contrary it is in continual movement owing to (*a*) the diurnal temperature variations, which cause differences between the soil and atmospheric temperature so that the air passes from the warmer to the colder medium whichever it may be (*b*) the permeability of the soil, the movement being very free in loose soils up to complete arrest in the case of a layer of cement or frozen ground,* and (*c*) the varying levels of the ground water and the occasional fall of rain, both of which naturally displace air from the pores of the soil. The understanding of these movements of the ground-air becomes of extreme importance when in addition to excess of carbonic acid and ordinary organic effluvia we have added the foul air, from leaky cesspools, defective drain pipes or sewage-sodden ground. Remembering the structure of an ordinary house in a cold climate, *viz.,*—deep foundations excavated, often in close proximity to leaking sewers or cesspools, to form cellars or a basement storey with a perfectly pervious floor of earth, brick, or badly pointed stones through which, owing to the high temperature of the house air, the ground-air is literally sucked in and ascends to supply the various rooms—it is not to be wondered at that many attacks of disease ranging from temporary

* Surgeon Captain Firth, A.M.S., Asst. Prof. of Hygiene, Army Med. School, Netley.

indisposition to a fatal issue are deemed insidious or even inexplicable.*

THE WATER IN THE SOIL—GROUND-WATER.

The water in the soil is divided for convenience into the moisture and the ground-water. Unless the ground is water-logged, as in swamps or temporarily after very heavy rain, there is usually a considerable amount of ground-air between the particles of the soil, which latter are merely damp or moist. This moisture is derived chiefly from rain by simple percolation but also from the water in the deeper layers of the ground by the latter's rise and fall, evaporation from its surface and by capillary attraction. In addition the actual amount of moisture will depend upon the absorptive power of the soil. This absorptive power varies very much with the nature of the soil; even rocks as dense as granite or marble contain one or two per cent.

At the level where the mixture of soil, air and water gives place to one of soil and water only, to the exclusion of air, the Ground or Sub-soil water begins. This is derived from the rainfall, but not necessarily directly, for in some cases the ground-water consists almost entirely of water which has flowed a considerable distance through the soil. It is *not a continuous underground sheet of water,* though such subterranean lakes or reservoirs do occur in nature, but a *network of soil with the interstices filled with water.*† In the same way it is not necessarily a horizontal network for its level varies locally according to the composition and disposition of the soil and the angle of inclination of the underlying impermeable strata. Anyone who has

* *v.* Note on p. 122. In such a case the air being prevented from escaping in a vertical direction travels horizontally till it finds an outlet, such outlet being only too likely to be the previous ground floor of a dwelling house.

† In the same way the soil above which is merely moist, may be looked upon as a network or porous structure of which the fibres or granules are thickened and swollen by moisture but the interstices filled with moisture laden air: *cf.* a cloth dipped in water and 'wrung out,' with a cloth lying *just covered* with water.

had much experience in digging wells knows that water is by no means always found at the same level even at short distances. The depth at which the ground-water lies varies within wide limits from just below the surface in water-logged soil to several hundreds of feet.* Again, the level of the ground-water at any one spot is constantly changing. In this country the level probably varies in ordinary years from five feet during the rains to about twenty feet at the end of the hot weather, but there are doubtless many exceptions to this, and the number of recorded observations is very small. Its level or depth below the surface at any one time depends upon the amount of antecedent rainfall and the ease or difficulty of the outflow: also, the *movement is not merely vertical;* there is *movement in a horizontal plane as well,* for the water is continually flowing, at rates varying from a few feet to several hundred daily, towards the point of easiest outlet, *e.g.*, the sea, a lake, a river, wells, or even the side of a declivity.† The rate of movement is influenced by the ease or difficulty of the outflow, the relative compactness of the soil and the presence or absence of vegetation, the flow of the water being very seriously retarded by the roots of trees and smaller plants.‡

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* When cesspits are dug and left uncemented in such permeable soils, they may be used for very many years and *never become full*, owing to the fact that the liquid matter, carrying with it a large proportion of the solid matter, continually filters into the soil, is thence carried down by the rainfall as it percolates and thus reaches the ground-water; the final result being frequent poisoning of wells situated even some considerable distance away.

† The practice of deep-drainage, so important both from the agriculturist's and sanitarian's points of view, is simply an artificial method of increasing the rate of outflow so that the ground-water is carried away more rapidly than would otherwise be the case. The outflow can also be rendered easier or 'opened' by cross drainage, cleaning water courses, etc.

‡ A point well worthy of closer attention than is given to it in certain parts of India where it would be advisable to conserve the rainfall by obstructing the outflow. In seasons of drought the level of the ground-water in cantonments, etc., may, by the ceaseless and unregulated sinking of wells, be so lowered that the deepest-wells run dry and a water-famine results.

GROUND-AIR IN RELATION TO DISEASE-CAUSATION.

Coming now to the influence which soil is supposed to exert upon health by means of its effect on the air of a place we shall find that this influence may be classified under two main heads, *viz.* :—1. A purely Local influence confined to one or two houses, 2. A more General influence affecting certain parts of a town or village and its neighbourhood.

From what has been said previously in discussing the composition of ground-air it can be easily understood how important a part the latter may play in disseminating disease. Given a soil contaminated with organic impurity due to defective drainage or the accumulation and downward filtration of filth, coupled with a defectively-built house, it is evident that the air-supply of the house is liable at any time to be rendered impure by simple excess of carbonic acid, by organic effluvia from sewage or by the addition of living disease contagia. The degree to which disease is thus spread is probably not so great in this country, considering the extreme impurity of the soil, as in colder climates where the difference between the external and internal temperature of houses is more pronounced, but there is little doubt that it is considerable.*

The more general influence of the soil upon the air of towns and districts is an extremely important question the consideration of which must be omitted for the present save only in connection with one important disease—Malaria. The following diseases have been supposed to be spread by the air from impure soils, *i.e.*, by the 'effluvia' or 'miasmata' of older writers. 1. Malarial fevers; 2. Enteric fever; 3. Yellow fever; 5. Dysentery; 6. Diphtheria.

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* *v.* Case reported in *Lancet* (1873, Vol. II, p. 592) where coal gas from a leaky gas-pipe was drawn into a house along with ground air, owing to the frozen-ground preventing its escape elsewhere, and caused poisoning of the inmates. Another case, where the poisoning was due to carbonic acid entering, during hard frost, a house built on soil 'made up' after quarrying, is reported in the B. M. J., 1893, Vol. I, p. 206.

Malaria.—Of the exact nature of Malaria—the poison which produces a disease characterised by paroxysmal fevers, neuralgias, enlargement of the liver and spleen and other well-marked symptoms, and terminating often in profound cachexia and death—not much is known with any certainty. The subject will be afterwards considered.* Most physicians are agreed as to its origin. It is generated by vegetable matter in the soil, undergoing slow decomposition, under the influence of moisture and a certain degree of temperature not less, it is supposed, than 67° F. (19·3° C.) It is probably not gaseous, because it appears incapable of ascending by diffusion to very great elevations, and because a thick belt of trees has been known to shelter from its influence. It can probably enter the blood and produce its poisonous effects, either by the air breathed or by the water drunk.

Although the causes given above are believed to be invariably present in malarious localities, they are sometimes co-existent in places where paroxysmal fevers and other effects of paludal intoxication are unknown. There are two well-marked Exceptions to the rule that sufficient heat, moisture and decomposing vegetable matter in the soil generate malaria. Peaty soils fulfil these conditions, (unless it be supposed that their well-known anti-septic properties prevent the decomposition of the organic matter which they contain) ; but in boggy countries, as in Ireland and parts of Australia, endemic paroxysmal fevers are unknown. Secondly, tracts regularly covered by the sea at each flow of the tide are not malarious, perhaps because the products of decomposition are washed away before they have reached the stage in which they become poisonous or because the malarial poison cannot live in such a saline soil. Besides these two exceptions, anomalous cases have been observed in various parts of the world where malaria might have been expected to be present but was not.

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* *v.* The Etiology and Prevention of Disease.

Knowing, then, the conditions necessary for its generation, it is easy to infer the places where it is likely to be prevalent. These may be briefly enumerated :—*Marshes*, in hot or temperate climates, whatever be the mineral constituents of the soil, containing dead organic vegetable matter to the extent of from 10 to 45 *per cent.* and abundant moisture, will be generative of malaria. Positions at the *foot of hills* which supply abundance of water are often unhealthy, exuberant vegetation being accompanied by accumulation of vegetable débris in the soil. The most deadly forms of remittent fever occur in persons who have incautiously exposed themselves to the influence of malaria in the jungles of this *terai* country, whether in India or Burmah. The apparently dry *beds of nullahs* and ravines generally have water at no great distance from the surface and often contain much decaying vegetation. *Sandy plains* with an impermeable substratum of rock or clay a few feet from the surface, which holds up water and keeps the soil saturated, may be highly malarious although bare of vegetation, owing to the presence of the decaying remains of previous vegetable growth. In some, vegetable matter, silicious particles and an oxide or other salt of iron become concreted into a nearly impermeable stratum from which the over-lying water slowly dissolves out the organic material and produces malaria. *Alluvial soils*, which constitute nearly one-third of the soil of this country, often consist of permeable beds alternating with impermeable strata of clay, retaining moisture in contact with abundance of decayed vegetation. These are undesirable sites, though it is impossible always to avoid them.* The *deltas* of large rivers are of this nature. *Salt marshes*, if only occasionally overflowed by the sea, are unhealthy. *Newly disturbed soil*, as ground brought into cultivation for the first time or cleared of brush-wood by up-rooting, is very likely, in this country, to be malarious. Even *rocks*, as trap, gneiss and granite, when softened by

* *v.* p. 128 and note.

disintegration, may admit water and organic matter into their substance by slow percolation and so generate malaria.* It is very improbable that their mineral constitution has any share in the production of this effect; but some have thought differently, and Heyne attributed the Mysore fevers to the decomposition of rocks containing ferruginous hornblende. Lastly, *irrigated lands,* as rice fields, fulfil the conditions for the generation of malaria, and in some countries are virulently unhealthy. In the Southern United States, for example, the rice plantations are almost uninhabitable, except by the black or mixed races, during the heat of summer. In this country Surgeon-General Cornish has pointed out that rice fields exposed to sea air are not sources of malaria, but that irrigation is not innocuous in inland districts. The proximity of rice fields or positions to leeward of them should be avoided for human habitations as far as possible.†

GROUND-WATER IN RELATION TO DISEASE-CAUSATION.

Thirdly, the soluble matters in the soil may affect health though the Water used for domestic purposes. Impurities introduced into the system by this means may be either organic or inorganic. The former include the specific poisons of cholera, enteric fever, malarious diseases, dysentery (?) and epidemic diarrhœa (?). This subject, however, as well as that of the inorganic impurities of water, has already been considered,‡ whilst the exact connection between the ground-water and certain of these diseases, supposed by some to be very intimate, will be discussed hereafter.§

The effects of the movements and of the level of ground-water upon health can easily be inferred from the above

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* This idea is ridiculed by Sir William Moore, with, I think, quite insufficient reason. But, apart from this, his discussion of malaria is well worthy of careful perusal. *v.* Diseases of India, 2nd ed., pp. 259 *et seq.*

† *v.* however McNally, *op cit.*, p. 116, para. 5.

‡ *v.* Chapter II.

§ *v.* The Etiology and Prevention of Disease.

description and from what has been already said about the results of moisture in the soil. The rise of ground-water may make a place damp and cold by saturating the soil above it, causing catarrhal and pulmonary diseases; or it may merely supply the moisture necessary to the generation of malaria or specific miasms. On the other hand its rise may check the production of these poisons by occupying and saturating with water the stratum which contains the organic matter to which they owe their origin. So, too, its fall, after wetting such layers of soil, may stimulate the production of malarious and miasmatic diseases; or its continued depression at a depth below their level too great to admit of their deriving moisture from it may have a highly beneficial effect. If the poison of malaria exists in the ground-air the rise of the ground-water after heavy rain will drive out the poisoned air and produce paludal diseases.*

HEALTHY AND UNHEALTHY SOILS.

From what has been said before, a good idea can be formed of what constitutes a healthy soil or the reverse. One important point remains to be noticed, *viz.*, the use in many towns of "made soils." Under this term is included any soil formed artificially by the deposition in any convenient hollow of earth dug out of the foundations for building and rubbish of all sorts such as street sweepings, house garbage and trade refuse from tanneries and other works. Such a practice is very common in crowded situations where land is valuable. It is objectionable from every point of view† but if permitted no building should be allowed to be erected upon it for at least five years.‡

* I have noticed a most marked *sudden increase* in malarial fever of the intermittent type at such a time during a period of heavy rainfall in Ganjam.—A. E. G.

† Including the builder's—I remember a row of houses in a Scottish town, which has partly subsided owing to the foundations being sunk in 'made soil'.—A. E. G.

‡ Seven years, even, has been found to be too short a space of time for complete disintegration of rubbish in Madras, *v.* Jones. Manual for District and Municipal Boards, 1888, p. 52. "Where lands have been reclaimed in

Ultimately the soil appears to purify itself but only if it is freely exposed to oxidation and the cleansing action of the rain. Above all things building upon soil which has been used at any time as the site of a cholera or other infectious diseases hospital or as a burying ground should be absolutely prohibited.*

Briefly then:—impermeable rocks as granite, gneiss and clay-slate, are generally healthy: the water from limestone and magnesian limestone strata is often excessively hard and sometimes unwholesome;† chalk, permeable sandstones, laterite (?) and gravels are healthy, generally yielding a pure water-supply: sands, if free from organic débris are healthy, but many are malarious and the water is often highly charged with saline impurities: clays and marshy soils, unless thoroughly drained, are unhealthy: the worst soil is artificial ground made by the deposit of miscellaneous rubbish.

IMPROVEMENT OF UNHEALTHY SOILS.

In many cases it is obviously impossible to choose a site merely because it would be a healthy one or to reject another site simply because it is unhealthy. The generality of human beings who have a choice at all are governed in their selection of a site by the purely social or commercial advantages it will afford, whilst for the vast majority of people there is no choice about it, they have got to reside where the means of making a livelihood exist. The Burman villagers, who never repair buildings, when their houses and

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the manner above related [*i.e*, by filling in with rubbish and earth in alternate layers], the local authority should place a decided veto against their being used as building sites or bustee settlement for at least four to five years, during which interval they may be used as grazing ground or plantations. After four or five season's cultivation they may safely be built upon by huts or light structures which will not require deep excavations to put in foundations. The local authorities in Bengal have ample powers under the Bengal Municipal Acts to control settlement on such lands and this is a matter that should be insisted upon in all cases." R. C. Sterndale, Vice-Chairman, Municipality of Calcutta, quoted by Jones, *op cit.*, p. 55.

* *v.* Trans. 7th Internat. Congress of San. Sci., Vol xi, p. 27.

† *v.* p. 84, paras. 3 and 4.

their surroundings become defective or markedly unhealthy simply choose a new site and build thereon a fresh village *de novo;* but it must be confessed they do not as a rule travel far enough. Alluvial soils are usually unhealthy owing to the large amount of organic matter present and to the stagnation of the ground-water. A great deal, however, can be done to improve many naturally unhealthy soils.

In order to guard against miasmata proceeding from the soil, the following precautions are advisable:—*drainage,* preventing sudden rises in the level of the ground-water and consequent forcing out of noxious gases, &c.; *raising dwellings from the ground* on poles, arches or solid basements; *exclusion of air from below* by concrete, asphalte or other impervious material in or beneath the floor; and, most important of all, *careful choice of site,* avoiding, if possible, alluvial soils,* and under no circumstances building upon soils artificially made up of rubbish containing organic matter. More especially, the precautions and remedies indicated by a soil which there is reason to believe to be malarious are—thorough drainage; cutting down to the impermeable sub-soil, if there be any, and in all cases deep enough to withdraw moisture from the stratum which contains decaying vegetable matter; raising the dwellings on solid basements three feet or more from the ground, or (better still) on posts or arches, admitting free passage of air beneath; interposing a belt of trees or a piece of water kept at a constant level between a site and an obvious source of malaria; excluding, especially at night, wind blowing from a malarious quarter; (when this is impracticable, as when it is necessary to sleep in the open air, the use of mosquito-curtains is said to be

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* From the sanitary point of view it is to be regretted that by far the larger number of important towns throughout the world are built, of necessity, upon low-lying alluvial soil. In such cases the chances of pollution of the soil, air and water are very much increased and the health of the inhabitants suffers in a corresponding degree.

beneficial);* avoiding disturbance of the soil through clearing away of brush-wood from a temporary position and choosing the hotter hours of the day rather than the morning or the evening for the work if the position is to be occupied permanently; *care to obtain drinking water from a source uncontaminated by decomposing organic matter*;† selection of sites as elevated as circumstances allow—because, though malaria is not unknown even at a height of 6,000 feet above sea-level,‡ its power is diminished by elevation, owing, probably, to the diminution of temperature.

Lastly, it is evident that the remedies for the evils due to changes in the level of ground-water are the improvement of existing and the opening out of new passages for the water towards its natural destination. Deep and effective sub-soil drainage will keep the ground-water below the level where danger begins. "Sanitary and Engineering authorities are all agreed that irrigation without drainage has a most evil influence upon health, and that deep drainage improves the soil as well as the health of the inhabitants. The efficiency of drainage should especially be looked to in irrigated lands. In most parts of Madras the natural drainage is good, but in some parts of Northern India flat tracts of sedimentary soil occur where irrigation water has no sufficient outflows, and in such places malaria prevails to an alarming extent. For instance, in 1885 in the town of Sunpat on the Delhi branch of the Jumna canal

* From experience gained in very malarious localities in Burmah I believe this to be an undoubted fact. It certainly lessens the risk of chill on cold, misty mornings before taking food or exercise. This practice is recommended also in the valuable and very practical hand-book for travellers issued by the Roy. Geo. Soc.—A. E. G.

† *v.* Instructive paper by Brig.-Surgn. Pringle, in Trans. 7th Internat. San. Congress, Vol. XI, p. 203.

‡ The elevation necessary to secure immunity from malarious influences varies in different countries and in different parts of India from about 400 up to 7,000 feet above sea-level. "Wherever malarial fever is endemic at more or less considerable elevations, the seat of the disease is always a valley with a small declivity, or a basin-like depression in a plateau, while the open levels, except so much of them as lie immediately at the foot of shelving mountain spurs, are, like the mountain ranges themselves, for the most part exempt." Geo. Path.; Hirsch, Vol. I, p. 265.

there were 833 deaths from fever in a population of 13,077, a rate of 63·7 per 1,000 per annum.* * * * The management of irrigation is a most important matter. If an increased volume of water be poured into a district, the channels, natural or artificial, which were previously sufficient for its drainage, may prove insufficient; a general stagnation and rise of sub-soil water and greatly increased unhealthiness may result. Hence when irrigation is resorted to, drainage should receive especial attention."*

EXAMINATION OF SOIL.

A complete examination of the soil of any locality includes an inquiry into the following points:—1. The Mechanical Condition of the soil. 2. The Temperature of the soil. 3. The Moisture of the soil. 4. The Composition of the Ground-Air. 5. The Composition of the soil. 6. The Animal and Vegetable Life in the soil. (2), (3) and (4) are sometimes grouped together under the term Soil-Meteorology, so that we may classify the examination thus:

I. Mechanical Examination of the Soil.
II. Chemical " " "
III. Meteorological " " "
IV. Biological " " "

Mechanical Examination.—Under this heading is included the estimation of the (*a*) Density, (*b*) Friability and (*c*) Permeability of the Soil. The two former can be estimated roughly by any one after a little practice. The degree of Permeability is best noted by having a hole dug about 10 feet deep with vertical sides. After the soil has become fairly dry, water is poured gently on the surface of the ground and the time it takes to percolate downwards is noted. By digging deeper or sinking a tube well the water level can be ascertained, and by digging holes at different

* McNally *op. cit.*, pp. 115-6. *v.* also Evils of Canal Irrigation and their prevention, T. Thornton, C.S.I., Journ. Soc. Arts, March 1888, and Report by Surg.-Major W. G. King on the Influence of Irrigation on the Prevalence of Malaria at Kurnool, 1880, etc.

places a short time after rain has fallen, a rough idea of the natural drainage of the soil can be formed.

Chemical Examination.—Besides the actual analysis, both qualitative and quantitative, the following points are especially important to be determined (*a*) The Percentage of water; (*b*) The Absorption of water by the soil after it has been dried; (*c*) The substances present which are Soluble in water.

Meteorological Examination.—This branch of the subject has received considerable attention in Germany and is undoubtedly of great importance. In this country, unfortunately, with one or two brief exceptions, neither opportunity nor encouragement have been afforded for similar investigations. The principle exception referred to is the series of observations undertaken by doctors T. Lewis and D. D. Cunningham and embodied in a report entitled "The Soil in its Relation to Disease."* The object of the researches was to determine to what extent peculiar conditions or changes of condition in the soil in Calcutta affect the prevalence of disease in general and of certain diseases in particular. Attention was paid to the three following points:—The amount of moisture in the soil; the temperature of the soil; the amount of carbonic acid in the soil-air. Such an investigation requires the very greatest care and technical skill and it is by no means easy to obtain a constant record of the true soil temperature at different depths. "It may be premised that the estimation of the amount of carbonic acid in the soil was not undertaken in the idea that the gas itself exerts much influence on the prevalence of disease but because its amount may be taken as a convenient and fairly accurate index of the degree of the various organic processes taking place between the water level and the surface." To those who have had the benefit of a scientific training it is self-evident that one series of observations is quite insufficient to give reliable

* *v.* Reprint of the report, with charts, etc., in "Physiological and Pathological Researches," by T. K. Lewis.

and useful results—"it is only on *prolonged and continuous observations in various localities** that definite conclusions can be based."

IV. *The Biological Examination.*—This method is also of great importance but requires special training and a good laboratory. There is no doubt that it will ultimately yield, in conjunction with the other modes of examination with which it is inextricably bound up, results of the highest practical importance. †

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* The italics are mine (A. E. G.)

† As it has already done in the case of Anthrax, Tetanus, Agricultural Science, etc.

CHAPTER IV.

REMOVAL AND DISPOSAL OF WASTE MATTER.

To a dweller in an ordinary English town it is difficult to realise the enormous amount of waste matter that is being constantly formed and almost as constantly got rid of. But as the traveller passes further east or south to the warmer and less civilised countries he easily enough begins to realise that in and around all the towns he visits there is a plentiful supply of waste and refuse matter of the most varied character, to which constant additions are being made and the removal of which is left chiefly, if not entirely, to the united exertions of crows, kites, pariah dogs, pigs, etc., aided by the powerful desiccating action of the sun and an occasional general clearance, or, it may be, only re-arrangement, during rainy weather. The subject is not a pleasant one, but it is of supreme importance. Given a good supply of water and fresh air the next most pressing necessity for a community is the paying of attention to the thorough and systematic removal of all waste matter.

Sources of Waste Matter.—As to the various Sources from whence such refuse is derived we find them to be as follows: I. Refuse derived from individual members of the general community, *i.e.*, from the Dwellings of men and other animals. Under this heading is included the waste from *latrines*, fæcal matter and urine—, from *kitchens*, food refuse, dirty water and ashes—, from *houses*, house-sweepings, etc.—, from *stables, cowsheds, piggeries, etc.*, fæcal matter, dirty straw, etc. II. Town Refuse. Under this is comprised the waste matter from *slaughter houses, streets, markets, public buildings* of various sorts, and *works* and *factories* of all kinds. Finally, in addition to all this is the question of the disposal of the Dead Bodies of men and the larger animals—a problem which may assume very considerable

proportions in time of war or pestilence. It will be separately dealt with hereafter. We have then to consider the following as to removal and disposal. A. Wet material or ordinary *sewage*. B. Dry material or ordinary *refuse*. [C. Dead Bodies of men and other large animals.]

In the same way as the various materials to be removed are divided into wet filth and dry filth, the numerous methods of removal are divided into two great classes, *viz.*: I. Dry methods of removal, *i.e.*, by *scavenging*. II. Wet methods of removal, *i.e.*, by *sewerage* or water-carriage systems. "The advocates of either sometimes argue as if one of these systems alone could be adopted to the exclusion of the other. This, however, is impossible, and both systems must always co-exist in well-ordered towns and villages; foul water has to be got rid of by sewers [or drains], and dry rubbish must be carted away. The only question which can be at issue is whether ordure or urine, or both, should be removed by cartage or by sewerage." * From which it can be seen that certain materials, *e.g.*, road sweepings, are always removed by dry methods, others, *e.g.*, waste water from houses and streets, if removed at all by artificial means, by sewerage, whilst yet a third class, of which human excrement, both liquid and solid, is the best and most important example, is sometimes removed by dry and sometimes by wet methods.

Before adopting any particular system the opinions of those persons chiefly interested must, if possible, be brought into agreement. These are the sanitarian, the agriculturist and the financier. To the former the chief object is effective and *speedy removal* of filth from the neighbourhood of human habitations, etc. The agriculturist wishes to restore to the land as much as possible of the fertilising material which has previously been removed from it in the shape of grain, vegetables, meat, etc., *i.e.*, he wants *manure*; but the manure must be thoroughly good and as free as possible from rubbish, such as glass, old tins, coal ashes,

* McNally, *op. cit.*, p. 98, and many others.

etc., and from excess of liquid which merely adds bulk without adding to the manurial value. Lastly, the financier, who represents the tax-payers, wants the *cheapest* system, whichever that may be. By mutual concessions, agreement is generally possible, but the sanitarian, in the discussion of any scheme of filth-disposal, must adhere firmly to the principle that the health of the people is of paramount importance.

In this country the dry methods of removal of human excreta are most generally suitable so that these will be considered first. A few preliminary observations, however, are necessary. The average amount of fæcal matter passed daily by each member of a *mixed** European population is about 2·5—3 ozs. In India, owing no doubt to the more bulky vegetable and farinaceous diet, the amount is considerably larger, about 7 ozs.,† but of this, about three-fourths consist of water. The daily amount of urine is about thirty-five ounces per head. When the urine and fæces are kept separate, decomposition proceeds slowly; conversely, when they are mixed, it sets in much more rapidly with liberation of ammonia, fœtid organic gases, carburetted hydrogen, carbonic acid, etc. Under a tropical sun fæcal matter passed on open ground very soon dries up into a mass that ultimately crumbles into powder which is partly washed into the soil by rain or blown into neighbouring houses, tanks or wells, etc. The personal ablution which obtains amongst the natives of this country, after obeying the calls of nature, adds about one-third more to the quantity of fluid to be removed and increases but slightly the difficulties in connection with the removal of excreta. Where a wet system of sewage removal has been applied to houses,‡ the squatting posture during the act of defæcation has necessitated the construction of special low-seated closets.

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* *i. e.*, a population composed of men, women and children, as distinguished from the populations of jails, barracks, schools, etc.
† 10 ozs., according to some (Dhurandhur).
‡ *e. g.*, in Bombay.

DRY METHODS OF REMOVAL AND DISPOSAL OF EXCRETA.

Under the above system of removal one of two plans may be adopted, *viz.*:—1. The excreta may be removed in the condition in which they are voided. 2. The excreta, before or after removal, are mixed with some substance with a view to deodorisation and the prevention of putrefaction.

Removal without admixture.—This is the plan adopted in many towns in India in connection with public and private Latrines.* The fæcal matter, with or without the urine, is collected for twenty-four hours or so and then removed by hand or by cart. The urine sometimes passes into a separate receptacle from whence it is also removed at intervals; at other times it flows away into the open street drains through a small opening in the outer wall of the house. In the case of European and the larger native houses the solid excreta are collected in a receptacle at the end of the compound and removed once in twenty-four hours by hand or by municipal carts, while the urine is generally emptied on to the ground by the sweeper.

Modifications of this plan are still in use in many European towns under the name of the 'midden' or 'pail' systems of conservancy. Middens† are simply latrines attached to one or more houses of the poorer classes and consist of pits for the reception of excreta only or excreta *plus* dry house refuse. Originally they were simply heaps

* These private latrines, as a rule, are filthy in the extreme. They may be seen, by any one curious enough, in almost any Indian town. The latrine itself is a small room, often just large enough to allow one person to squat. In the centre is a small slit about 6 × 4 inches in size through which the fæces are passed into a dark noisome hole in the ground of uncertain depth. This pit or well is very rarely emptied; when it is, the whole air around is polluted. In some towns a basket is placed for the reception of the solid matter, the urine dribbling away into the ground or into a neighbouring surface drain. Of course, the larger part of the so-called 'solid' matter frequently drains away as well. In other cases the excreta are passed simply on to a smooth surface sloping outwards, down which the urine flows to the open sewer-drain outside the building. The solids, sometimes after the addition of wood-ashes, are removed by sweepers at intervals. *v.* the writings of Kanney Lall Dey, also several papers in Vol. XI of the Transactions of the 7th Internat. San. Congress.

† The terms 'midden' and 'cesspool' are not, as is frequently supposed, synonymous, *v.* Cesspools, *post.*, also S. & M., Vol. I., p. 823.

of decomposing and evil-smelling filth, but in later years it became the practice to dig a hole in the ground so as to conceal these accumulations from the eye at least, if not from the nose. The filth is allowed to accumulate for a certain time, it may be for months, and is then removed by scavengers, a most disagreeable process for all who live in the neighbourhood. If such a midden or privy is allowed to exist, it should be *small*, so that it must be emptied frequently, *shallow* and *watertight*, to prevent leakage, *roofed over*, to keep out the rain and *well ventilated*. In addition, while *easy of access* it must be situated at a *safe distance from the house ;* not placed within the house as is almost invariably the case in this country. As a rule, in English middens sifted ashes or other house refuse are added to the excreta so as to keep them dry and in as inoffensive a condition as possible. This really places them under the next division, *viz.*, removal after admixture.*

In the Pail system, of which there are several modifications, each household is supplied daily by the municipal scavengers with an empty receptacle, the full receptacle being removed at the same time. These pails are made with air-tight lids to abate the nuisance of odour as far as possible, and are sometimes (Goux system) lined with compressed stable-litter or other material which absorbs the urine and thus retards decomposition and prevents spilling of the liquid during transit. The so-called 'bucket' system in use in many towns in India, *e.g.*, Madras, is a modification of the pail system, but in this case the pails or buckets are not supplied to each household. The sweepers

* The student should note that it is impossible to describe or classify all the various methods of refuse removal and disposal in a cut-and-dry fashion. There are so many modifications and combinations of the methods under different conservancy systems that any rigid classification is hopeless. This is well shewn by a reference to the following tabular arrangement of the subject (from Wilson Hand-book of Hygiene, 6th ed., p. 303.)

1. The water system.
2. The privy or midden system.
3. The pail system.
4. The dry system.
5. Lieurnur's and other continental systems.
6. Systems best suited for rural districts.
7. Disposal of slops.
8. Public scavenging.

pull the buckets, which are mounted on wheels, along the streets and into them the house-sweepers empty the privy contents from the houses as the buckets pass along the street.*

Removal with admixture.—Under this heading are included all the various systems in which some substance is added to the excreta with a view to deodorisation, the retarding of decomposition and, in some cases, disinfection (?). As mentioned above, such addition is frequently made in the case of middens, chiefly in the form of coal-ashes from the house fires. Numerous forms of screen-closets are in use, in which there is an arrangement whereby the ashes are automatically sifted so that the finer portions fall through a sieve on to the excreta. Again, coal-ashes or some special deoderant may be added to the pails instead of the absorbent lining mentioned before. It should be noted that coal-ashes have but a slight deodorising power whilst wood-ashes, which are always available in this country for use in small households, have a very strong deoderant and anti-putrefactive action. Pure charcoal of course exercises a still better action in the same direction, but is usually very expensive. It is quite possible, however, that in a town with several large 'destructors'† constantly at work, a sufficient supply of charcoal could be obtained from the 'carbonisers' to permit of its utilisation in the above manner.

In some countries, especially Germany, numerous special deodorising powders have been used, consisting of mixtures of charcoal, tar, carbolic acid, iron salts, etc., in varying proportions and in India McDougall's powder, creolin, Jeye's disinfecting fluid, etc., have been tried. Some of these preparations are but little use, others smell objectionably and nearly all of them are very expensive when used in large quantities. In special cases, *e.g.*, typhoid fever, where the excreta are suspected of containing specific

* *v. post.* Sanitation of Towns. † *v.* p. 145.

poisons the use of carbolic acid or other substance as a *disinfectant* may be very necessary, but that is quite a different thing to the routine deodorisation of large quantities of healthy excrement.

One material there is, however, which is cheap, destroys all odour almost instantaneously, and is nearly always easily obtainable, *viz.*, Earth. With this system of the addition of earth to excremental matters is associated the name of the Rev. Mr. Moule, a clergyman who strongly advocated the practice. All earths are not equally suitable; the best are loamy surface soil, vegetable mould, brick earth and dry clay. Sand is very little good. The earth must first be dried in the sun (or over a special stove in the rains) and then 'sieved,' the coarser portion being rejected. The closet consists of a seat to which is attached a 'hopper' filled with the dry earth. (*v.* plate vi.) Every time the closet is used one-and-a-half pound of earth is discharged on to the newly-passed excrement,* both being received into a movable pail placed under the closet. When the pail is full it is removed and its contents emptied into a trench in the ground and covered up. In a short time the fæcal matter, and even paper, becomes completely disintegrated, the ultimate result being the production of a rich 'garden mould.' Unfortunately, the manurial value of the product is not nearly so great as one might naturally expect, owing to the fact that a large proportion of the nitrogen contained in the voided urine and fæces passes into the atmosphere in a gaseous form. For a like reason it is possible to use the same earth several times over after keeping it for sometime, drying and powdering it, but even then its manurial value does not increase to any appreciable extent. The system is a very valuable one for isolated houses or institutions, *e. g.*,

* This amount of earth must be increased in this country for the two reasons already noted, *viz.* :—the larger amount of the fæces and the use of water for ablution. In Alipur Jail Mr. Fawcus found 5 lb. of *undried* earth necessary for the fæces and 8 lbs. of the same for the urine of healthy Hindus. If the earth is dried and of suitable quality, as explained above, and the urine and water allowed to drain off into a special receptacle, a much smaller quantity will suffice, say 3 lbs. *v. post.* Practical Sanitation.

jails,* hospitals, temporary camps, etc., but in the crowded portions of large towns it is difficult to work and very expensive, especially during wet weather.†

Disposal of Excreta.—Whether, therefore, the excreta are removed with or without admixture the method of their disposal remains to be considered. There are really only two ways of disposing of solid fæcal matter, whether mixed previously with earth, etc., or unmixed, and these are (1) by returning it to the soil; (2) by destroying it by fire. The final result is the same in both cases, *viz.*, the reduction of the complex organic compounds to simpler and harmless inorganic combinations with evolution of various gaseous substances. But there is one important difference. In the case of fæcal matter exposed to the action of intense heat there is absolute destruction of all living organisms and their spores; in the case of fæcal matter merely returned to the earth there is no such guarantee. If we were sure that all the fæcal matter was derived from healthy individuals this would be a point of no importance, but we know that the contrary very frequently obtains and that the stools of persons suffering from cholera, typhoid fever, etc., are mixed up with those of others. We further know experimentally and practically that many micro-organisms, or

* It is largely in use in Indian Jails. Moule's closets are not used, the excreta being simply passed on to the sloping floor of the latrine or into chatties, but the principle is the same. Lately, an ingenious device, known as Donaldson's 'Night-soil Ejector,' has been applied to several Jails, whereby the excreta and earth are placed in a large hopper on the *inner* wall of the Jail, the hopper being continuous with an iron casing containing an Archimedean screw. The iron casing terminates in an opening on the *outer* side of the wall. By turning a handle attached to the screw the fæcal matter and earth are intimately mixed and the mixture received into baskets in which it is conveyed to the Jail-garden. The advantages claimed for it are (1) That it prevents the *toty* or *mehter gangs* from introducing forbidden articles. (2) That it obviates the removal of night-soil through the Jail, and the consequent trail of pollution in the air. (3) That it saves 30 per cent. of the labour. (4) That it removes any risk of the night-soil being buried in large pits. (5) That it involves more thorough mixing of dry earth and night-soil. For further details and illustrations *v.* Proceedings San. Com., Madras, 1891, p. 228 *et seq.*

† A suitable closet was devised by C. Turner, C.E., Southampton, for use in the ordinary native household, but, like many other improvements relating to India, its expense has prevented its general adoption. For further details regarding the various latrines suitable for use in connection with dry methods *v. post.* Practical Sanitation.

their spores, can multiply, or, it may be, merely lie dormant in the soil and only await a suitable opportunity to become the exciting cause of a dire epidemic.* There is but little doubt that soil saturated with the germs of infectious diseases, has directly—on being disturbed for building purposes, encampments, etc., or indirectly—through pollution of the water-supply, been the cause of many obscure outbreaks of disease.† It is also alleged by some that entozoic diseases may be spread by means of the earth-burial of fæcal matter. This is doubtful.

Though not a perfect system it is better than many others, if the following points are attended to :—(1) The earth must be *dry, well powdered* and of the *proper kind* ;‡ (2) Each individual stool, whether passed into a common receptacle or not, must have a charge of earth applied to it *directly* ; (3) The mixed product should not be allowed to accumulate in heaps but should be *removed daily* or *as often as possible* ; (4) It should not be buried in pits, but in *shallow trenches* about one foot deep ; (5) The spot chosen should be as near as conveniently possible, with due reference to avoidance of contamination of water-supply, and the soil should be of a suitable nature.§

In many towns in Great Britain, the pure excreta or the excreta mixed with straw, etc., impregnated with urine are removed daily and sold as manure. Where coal-ashes or other inorganic refuse is added the resulting product is practically valueless and is disposed of simply by spreading it on waste land along with the rest of the town rubbish, or by fire. The latter method is most conveniently considered under the next heading.

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* *cf.* Earth-burial and cremation: *v.* also Sir W. Moore's paper on Sanitary Progress in India, Trans., 7th San. Congress. Vol. XI, p. 26 *et seq.*

† The following Extract is taken from Sir William Moore's paper *loc. cit.* "* * * A party of coolies employed on a railway cutting near Salem, opened a spring of very clear water. Those who drank of it were seized in a few hours with cholera of a very severe type. In this instance the railway cutting passed through an old burial ground." *v.* also Admin. Report, Madras Municipality, 1891-92, Appendix vii, p. 239.

‡ *v. ante*, p. 139.

§ In many cases, part of the soil removed in digging trenches can be used, after preparation, for application to the excreta.

REMOVAL AND DISPOSAL OF TOWN REFUSE.

By the above title is indicated all the dry refuse which is collected daily by municipal scavenging carts* and brought to certain selected spots or *rubbish depôts* for disposal. In Europe it consists essentially of the ashes, dust, food refuse, etc., from houses, public markets and other buildings, and of the street sweepings, which are made up of road-dust, the excreta of horses and other animals, straw, paper, dead leaves, etc. In this country there is a considerable difference in its composition. The roads and streets are not regularly swept by special machines, partly because they are macadamised and not paved, partly because of the usual absence of mud. They are swept however to a certain extent by hand, the sweepings consisting largely of dead leaves, straw and horse dung. The droppings of cattle are almost entirely collected by private individuals on account of their value as fuel. The house refuse is also different in many ways, consisting chiefly of vegetable refuse, plantain skins, leaf plates and wood ashes.

The ultimate disposal of the enormous amount of refuse-matter thus collected is a very difficult matter. In England all sorts of ways and means are adopted. It is sometimes sold† or given to brick-makers; mixed with lime and used

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* For further details as to removal *v. post.* Sanitation of Towns.

† "The ultimate disposal of dustbin [dry] refuse is a matter for the serious consideration of local authorities. The old system still obtains at many places of carrying the refuse to a large sorting yard, often in close proximity to inhabited houses. Here men and women are employed in sorting the refuse and separating it into *breeze* (cinders and small particles of coal), *hard core* (bottles, bones, crockery, metal pots and pans,) and *soft core* (animal and vegetable organic matters and textile substances). The breeze is sold to brickmakers; the hard core, or such parts of it as are worthless, is used in road-making; and the soft core is mixed with fish offal, market sweepings, and horse droppings, and sent into the country to be sold as manure. The whole process of sorting is a noxious one, and degrading to the work people; and the foul odours given off during the process, and also from the heaps of refuse awaiting removal, whilst fermentation and decomposition are at work, often prove a most serious nuisance to the surrounding neighbourhood." (Murphy and Stevenson, *op. cit.*, p. 809). In many towns in Great Britain and the continent there is a miserable class of people known as 'rag pickers' (in France as *Chiffoniers*) who earn a scanty livelihood by coming out of the horrible dens they live in after dark, spending the night in 'sorting' the dustbins placed in the street

as manure for stiff clayey soils; mixed with the 'sludge' from sewage farms* and dug into the soil; used for filling up hollows and depressions in the soil;† or lastly, taken out to sea in hopper barges‡ and sunk in deep water.§ "The universal manner of disposal of town refuse in this country is by throwing it into pits, tanks, ponds and low grounds."|| This unfortunately is only too true and the process may be seen on any scale, commencing with the small mounds of household refuse deposited daily by the careful housewife around her dwelling, in immediate proximity to the shallow well or tank which constitutes the water-supply. The usual custom is to empty the carts, laden with town refuse, day by day on the selected bits of waste ground and then, after levelling the rubbish, to add six inches depth or so of earth. In practice the layer of earth is usually very much less and, if the supervision of the sweepers is not very thorough, there will be no earth added at all. In some towns the excreta are here intentionally deposited as well; in all towns there are sure to be excreta mixed with the rubbish. Such a 'made soil' is certain to be chosen by enterprising persons as a good site for building upon and stringent regulations are required to prevent this for a long time. In Madras seven years have been found insufficient for thorough disintegration of the waste material.¶ Such land should be brought under cultivation as speedily as possible, preferably by utilising it as a sewage farm, as has been done in Madras.** Even if such a place does not become a focus from which epidemic disease radiates,

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and abstracting from them anything eatable (!) or saleable before the scavenger's cart arrives. They may be seen in plenty in Edinburgh or Paris. In the latter city they have lately been disturbed in their occupation and ordered to quit the wretched quarter where they live amidst the filthiest possible surroundings.

* *v. post.* Disposal of Sewage. † *v.* Soil, p. 126.

‡ Large flat boats with moveable bottoms.

§ In New York, U.S.A.—about 800,000 tons of refuse are thus annually disposed of. For further information on this matter and many interesting details. *v.* Mun. and San. Engineer's Hand-book, Boulnois, 2nd ed., chap. XIX.

|| Manual for Dist. and Mun. Boards, Jones, Madras, 1888, p. 52.

¶ *v. Note* p. 126.

** *v.* Appendix, Madras Sewage Farms.

it is certain to be a nuisance to all who are unfortunately obliged to live in the neighbourhood.

After all, there is only one way of satisfactorily disposing of the enormous dry refuse accumulations of large cities, and that is by Fire. The proposal to do this apparently originated with Mr. Hickey, of Darjeeling, though his proposal had reference, strictly speaking, to the *distillation* of the excreta in retorts, with or without previous admixture with charcoal. Soon afterwards Mr. Stanford, in England, proposed much the same thing, the charcoal to be derived from the carbonisation of sea-weed which abounds along the littoral in that country. The charcoal is primarily added to the excreta when they are passed in the closets, to act as a deodoriser, etc.* This entirely does away with all offensiveness but does not disintegrate the fæces, as in the case of dry earth. The mixture is afterwards distilled, the charcoal being thereby recarbonized and fitted for use in the closets again, whilst the final condensed products of redistillation are ammoniacal liquor and tar, from the former of which sulphate of ammonium and acetate of potassium are obtained. The charcoal ultimately becomes charged with potash and phosphates and, after the addition of the ammoniacal products of distillation, forms a valuable saleable manure. The initial expense of the apparatus and materials and the difficulty of finding a sale for the chemical products have militated against the success of this plan of 'carbonisation' in India.†

Following this idea of carbonisation came the proposal‡ to expose all kinds of refuse matter to the action of fire, whence there have gradually come into use those somewhat elaborate buildings known under the generic terms of Destructors or Incinerators. The methods now adopted in the latest patterns of these structures have only been

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* ½ lb. only of charcoal is necessary (*cf.* dry earth, p. 139.)
† *v.* Parkes-Notter, p. 131.
‡ By Messrs. Meade & Co. *v.* Boulnois *op. cit.*, p. 270.

arrived at after many failures and determined opposition.* Those of Messrs. Fryer and Harrington are probably the best known.† One great difficulty, which has now been successfully evercome, was that owing to careless feeding of the furnace and to the excessive draught created, the process of combustion was incomplete, and noxious and evil-smelling vapours, along with small particles of unconsumed refuse, etc., were carried up the chimney into the open air. By the introduction of Jones' 'Fume Cremator' in which all the products of combustion are exposed for a second time to the action of a bright fire, this objection has been obviated.‡ A modern Destructor consists essentially then of the following :—(1) A *destructor* proper in which the bulky inorganic refuse such as cinders, broken earthenware and glass, old tins, etc., is exposed to the action of fire and reduced to 'slag'; (2) A *carboniser*, which receives street sweepings, vegetable refuse, offal, etc., and reduces them to carbon; and, in some cases, (3) a *concretor*, wherein the excreta are collected and dried, the ammonia being 'fixed' by sulphuric acid fumes derived from the carboniser and destructor. The slag or 'clinkers' is largely used for

* *e.g.* in Calcutta. In Madras, Ootacamund and other Municipalities may be seen disused examples of these ancient crematoria, which undoubtedly, owing to imperfect combustion, etc., were a decided nuisance when in action.

† Garlick's incinerator is being erected in Bombay and will shortly be put upon its trial.

‡ Experiments which were made in connection with this invention gave the following heats of the vapour:

Temperature in the Flue	...	... 610° F.
"	... Fume Cremator	... 1270° F.
" ...	after leaving the Fume Cremator	1100° F.

"At these temperatures and in presence of the accompanying air (about 13 tons of air are required to burn 1 ton of refuse), all septic poisons are destroyed, and organic compounds resolved into carbonic acid, water and nitrogen gas; only the minutest traces of empyreumatic products could survive and pass into the atmosphere. No harm to the health of the community is to be expected or feared from these products." W. Warner quoted by Boulnois, *op. cit.*, p. 269. The 'Smoke-Scrubber' in Harrington's incinerator is something of the same nature. In this case the smoke is drawn into a 'fan water wheel' into which water plays. The smoke is whirled round in the fan and washed by the water. It afterwards passes through a tatty screen against which water is playing. The soot, etc., from the smoke being deposited on the tatty work is washed away by the water which flows away into a drain. Finally, if desired, the smoke, as in Jones' Fume Cremator, is passed over several bright coke fires and is thus rendered imperceptible as it issues from the chimney.

roads and foot-paths, filling up holes and depressions in the ground, etc., or is ground into powder, mixed with lime and made into mortar, or mixed with cement and made into artificial stone for street paving, etc. The charcoal from the carboniser has many uses in connection with municipal and manufacturing operations, while the product of the concretor forms a valuable manure of moderate bulk. There is little doubt that this system for the disposal of dry refuse is very suitable for large towns, whether the excreta are included or are disposed of along with the sewage. It is at the present time in successful operation in Calcutta, and will in all probability be applied in Madras shortly, in which city the quantity of dry refuse removed daily is enormous. The heat generated during the combustion of the refuse has been utilised in various ways and it is at present under consideration to utilise it for generating steam for the engines required to drive the dynamos of the Madras Electric Tramways Company.*

REMOVAL OF REFUSE BY WET METHODS—WATER-CARRIAGE SYSTEM.

It has before been stated that even if the solid refuse of a town, including the excreta, is removed by a dry method, there still remains the waste water (*sullage*) from cooking, bathing, washing, trade operations, rainfall, etc., to be dealt with and that some system of removal of the impure fluid *must* be adopted in every town.† Great stress is laid upon the above fact as it is so frequently overlooked. It is necessary also to pay careful attention to another point. The waste waters from houses, stables, streets, markets, etc., contain a very large amount of foul organic matter of an easily-decomposable nature, such as grease or fat, soap, dirt from clothes and the bodies of men and other animals, urine, slaughter-house and market offal, etc.,

* *v.* Letter from the Health Officer to the President, Municipal Commission, Madras, 30th November 1892.

† *v.* p. 134. Conversely, even though the excreta and liquid waste of a town are removed by a sewerage system it is absolutely necessary to have some method in force for the removal of dry refuse.

etc. In addition, in towns where the excreta are not added to the drains, the sewers are not constructed with the same care and expense; the removal of the sewage is therefore not so rapid and complete and the consequence is that the sewage undergoes more extensive decomposition or fermentation. It is then said to be 'stale,' in which condition it is very offensive and dangerous to health. It has been proved* that there is a "remarkable similarity of composition between the sewage of midden towns [*i.e.*, excreta removed by dry methods] and that of water-closet towns [*i.e.*, excreta added to the sewage.] The proportion of putrescible organic matter in solution in the former is but slightly less than in the latter; whilst the organic matter in suspension is somewhat greater in midden than in water-closet sewage." It follows, therefore, that even though the excreta of the population are excluded—with open sewer-drains there never is any certainty that they *are* excluded—there *still remains a large volume of highly impure waste water to be disposed of, and no method of disposal can be considered suitable, which is not equally applicable to the sewage of towns having a complete water-carriage system*: in other words, the sewage in the former case is as impure, as objectionable and frequently as dangerous as in the latter.†

It is evident from the foregoing that sewage may have

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* *v.* First Report of the Rivers Pollution Commissioners.

† To any one who is sceptical about this matter, my advice is as follows:—Go to some town where there is a wet system of removal in force but in which the excreta are not added to the sewage and, paying a visit to the outfall of the main sewer, watch the black, greasy fermenting liquid pouring out ceaselessly. Then imagine for the moment that no such sewerage-system existed and that that enormous volume of liquid filth was allowed day by day, year by year to sink into and pollute the soil whereon the town was built. Which method of getting rid (*sic*) of waste 'water' is likely to be most beneficial to the health of the inhabitants? Yet the latter method has been in force for hundreds of years, if not longer, in ninety per cent. of Indian towns. What *does* flow away into the nearest watercourse or tank under such a *natural* system of drainage is not the original sewage, but the effluent after the sewage has undergone a process of 'downward filtration' through the soil of the town; the *immediate* result being a filth-sodden soil, a filth-laden atmosphere and a water-supply from the town wells of the nature of liquid sewage. The *final* result is best indicated in the death-roll of the town.

a very variable constitution and as a matter of fact it may consist of any of the following mixtures :—

(a) Waste water.

(b) Waste water + Excreta (*liquid only* or *liquid and solid*).

(c) Waste water + Rainfall (*ordinary*, including sub-soil water).

(d) Waste water + Rainfall (*total, i.e.*, including 'storm water.')

(e) Waste water + Excreta + Rainfall (ordinary or total).

But whatever its nature, it has to be got rid of in much the same way, *viz.*, by causing the *sewage* to flow along *sewers* or drains,* which latter, taken collectively, form a *sewerage system.*

The sewerage arrangements of a modern town such as London or Paris are very elaborate and costly, but, like the methods of water-supply and artificial ventilation now in use in such towns, they were originally highly primitive. From such a primitive condition the ordinary Indian village has not yet emerged, and in this country we may see examples of the sewerage system in all stages of development up to the latest and most ingenious of all, *viz.*, the 'Shone' system as adopted by Rangoon and which will be afterwards described.

In its simplest expression a drain consists merely of a small channel scraped in the earth alongside a dwelling and is exactly the same as the drains used by cultivators for irrigating their gardens. It is of course totally inadequate for carrying off liquid refuse efficiently. The suspended matters are soon deposited, owing to the slow rate

* The word 'drain' will be used principally in this work to denote open or uncovered sewers as distinguished from covered drains and sewers proper. There is considerable confusion in the writings of various authors in this respect In England, where open sewers are now almost unknown, except in country districts, it is becoming customary to restrict the use of the word drain to pipes or channels used for draining land whilst *all* channels carrying sewage, whether open or closed, large or small, are known as 'sewers.'

of flow, and the liquid rapidly sinks into the ground through the porous soil out of which the channel is formed. The next stage of advance is seen in those drains made by digging channels of various depths, with rectangular or sloping sides, and paving them with bricks or slabs of stone laid in mortar. Such drains may be seen in any Indian town in abundance and in most military or police 'lines.' They are well shown in the illustrations on the annexed plate. As a rule they are badly laid with respect to gradients, the bricks used are sun-dried country bricks which soon break and crumble, the mortar drops off and leaves interspaces in the sides and bottom through which the sewage percolates into the subsoil, and they are altogether inefficient.

In many towns, however, a much better class of drain or open sewer has been introduced, consisting either of good brick or stone slabs set in cement or else made entirely of concrete, as illustrated. In such cases the levels are carefully taken beforehand and the gradients properly adjusted so as to secure a flow that is neither too slow nor too rapid, sharp corners are avoided and the junctions of the drains are curved and in the direction of flow.* Being faced with cement which forms a smooth, even surface there are no obstructions to the flow of the liquid, the drains are easily kept clean by simple mechanical devices† and, if properly looked after, there are no cracks or fissures through which the sewage can escape into the soil beneath. To such drains there is one great objection, principally on æsthetic grounds, *viz.*, that being open, the sewage is visible to the eyes and appreciable by the nose.‡ This is a perfectly

* *v. post.* p. 162.

† In Madras, a wooden instrument with a head that fits the section of the drain is used. Sometimes a ball of straw is pushed on in front of the wooden cleaner.

‡ It is quite possible that there are far more serious grounds of objection, for it is at least doubtful whether the foul and sluggish-flowing liquid undergoing rapid evaporation and decomposition under the rays of a tropical sun, and in immediate proximity to the verandahs of the shops and houses in the bazaar, is not a direct and exciting cause of serious disease. The subject is discussed, from the engineering point of view, in Wallace's San. Engineering in India, Chap. V., *q. v.*

legitimate objection and the question comes to be whether closing the drains will lead to the creation of greater evils than those complained of. This question has long been answered in the negative by sanitary authorities in Great Britain and other civilised countries and the practical result is that from beginning to end the sewers in all large towns are closed, save for special openings for ventilation and inspection. In the early part of this century, when sanitary engineering was in its infancy, the knowledge of sanitary reformers was not commensurate with their zeal, so that in their hurry to remove all sewage from sight and smell they constructed elaborate and costly sewers on very defective principles. As a result very serious evils were produced and the plan of closing all sewers became discredited. During the last twenty years, however, enormous improvements have been made in the construction of sewers and all appertaining thereto and the consequence is that for large towns situated in countries with a temperate climate there is really no other system worth considering practically.* In India, however, it is a very different matter owing to climatic, social and other local conditions: and the subject will be discussed later on. Apart from this, it is quite necessary that every one who pretends to a knowledge of hygiene should understand at least the rudiments of a modern sewerage system and, accordingly, such a system will be described briefly from its commencement in the dwelling house to its termination at the outfall of the sewer.

Cesspools.—Before doing so, however, we must study the connecting link between simple drains or *gutters* leading into the nearest tank or nullah, and a modern sewerage system where the sewage is completely disposed of at the point of discharge. This connecting link we shall find in Cesspools or Cesspits as they are variously called. Such cesspools formerly existed in great number in England, in fact they

* The excreta of the population in these towns are not *necessarily* added to the sewage: it is only stated here that practically all large towns have a system of closed sewers.

were almost universal in connection with the better class of houses. In certain parts of India they are in common use and in Rangoon, before the introduction of the Shone system of sewerage, the ground was literally 'honey-combed'* with them.

A primitive cesspool consists simply of a hole dug in the ground, into which the excreta and waste water from a house or collection of houses pass directly or by means of drains. In England many of the cesspools were formerly constructed directly under the basement of the house, the air of which, as a consequence, was fearfully polluted and was the direct means of conveying disease to the inmates. In other cases the cesspit was situated at some distance from the house, to which, however, it was connected by an unventilated drain. Such a drain simply acted as a ventilating shaft *from* the cesspit to the house. In addition, the walls of the cesspit being porous, the liquid matter escaped into the subsoil and polluted any wells in the vicinity.† Sometimes the cesspool had an overflow

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* *v.* Trans. viith, Internat. San. Sci. Cong., vol. xi, p. 179. "Cesspools constructed in brick, stone and other materials are in common use, and large earthenware jars sunk in the ground are also used as cesspools, and are emptied at periods more or less remote." Baldwin Latham. "For the disposal of sewage and other filthy liquid, a system of cesspools, called 'khalcoovas,' prevails in Allahabad. A 'khalcoova' is in construction like a dry well. On a wooden kerb a steining of bricks is built dry without mortar in the joints, so that water may easily find its way through it, and this brick cylinder is sunk to within a few feet of the subsoil water-level. The top of this well, about five feet below ground level, is arched over with a brick and mortar dome; a connection with the house drain being made, earth is filled in over the dome. All the sullage water of the house is run off into the 'khalcoova'—all the bathing water, the kitchen water, the urine, the washings of the privies, and every conceivable liquid filth. All the liquid thrown into this khalcoova or cesspool filters through the sandy soil at the bottom and sides and finds its way into the subsoil water, and thus these khalcoovas are kept in working order, without opening and cleaning out, for more than 30 or 40 years. But the result of the system has been that the water of all the wells in the city is so much polluted as to be quite unfit for drinking. Most of the wells in the city are so badly affected by these khalcoovas that their water is too brackish to be drinkable in any form whatever; however, this water is freely used for washing, bathing and all other domestic purposes." Runchorelal Chotalall, President, Ahmedabad Municipality. *v. op. cit.*, *supra*, which contains many other references to the same subject.

† *v. supra* and note, p. 121.

pipe which discharged the liquid matter into a neighbouring stream or into a sewer. In the former case the pollution was just as great as if the house drain opened directly into the stream; in the latter case it would have been much better to have no cesspools at all, the house drain itself being connected with the sewers.

If cesspits must be constructed for isolated houses or small villages, great care must be taken to see that the following conditions, which have reference to the prevention of leakage and to the backward passage of foul air, are complied with in detail. The walls of the cesspit must be made of brickwork set in cement; the interior must be lined with cement; the exterior must have a backing of clay-puddle all around and beneath of from 9—12 inches depth. The roof and bottom must be arched, not flat, and the roof must have a ventilating manhole. The bottom must be built with a fall at the distant end so that the sewage can gravitate or be pumped if necessary. Between the house and the cesspool must be situated a ventilating disconnecting trap on the house drain and the latter must be constructed air and water-tight.*

With regard to disposal of the contents, they may either be allowed to flow away directly into irrigation drains in the proximity of the cesspool, or else a *strainer*, or screen of galvanised iron wire, may be inserted in the higher portion of the cesspool so as to separate the liquid from the solid contents. The liquid is then allowed to gravitate from an overflow pipe into subsoil irrigation drains, whilst the solids are removed daily by hand and dug into the soil.

On the continent in Europe the cesspool system is still largely in use. Large cement-lined spaces are constructed in the immediate neighbourhood of the houses, and are emptied three or four times a year. The pipes from the closets lead directly into them and are never properly flushed. The emptying is done by means of barrel-shaped

* *v.* p. 159.

carts (*tonneaux*) which act as receivers. In addition, there is a small engine which works a steam vacuum pump for exhausting the air in the receiver. This latter is connected by a hose with the cesspit and its air exhausted. Then, by turning a valve, the receiver is put in direct connection with the cesspits and their contents are drawn into the receiver. The whole system is unsound in principle and disagreeable in practice.*

According to modern sanitary principles it is essential to *remove all decomposing or decomposable matter at once* from the neighbourhood of dwellings. Cesspits do not comply with this principle and should only be permitted therefore in special cases and after absolute compliance with the aforementioned rules of construction.

A MODERN SEWERAGE SYSTEM FROM HOUSE TO OUTFALL.

Baths, Sinks and Closets.—In Great Britain the ordinary system of closed sewers may be said to commence within the individual houses of which the town is composed, but it does not necessarily do so.† Inside the house there are, respectively, *baths* for ablution of the entire body and in some cases *fixed basins* for washing the hands and face, *sinks* or receptacles for receiving waste water of all kinds, and finally *water-closets*‡ or receptacles into which the excreta are passed or emptied as the case may be.

The Baths and Sinks are made of various materials, *e.g.*, lead or zinc painted with enamel paint, enamelled stoneware, porcelain, etc., and are of various shapes and sizes.

There are also many kinds of Closets of which the lead-

* It matters little what precautions are taken in emptying cesspits, a nuisance is almost certain to be created, as any one who has walked about the streets of a continental town at night or in the early morning well knows.

† It is quite possible, as will afterwards be seen, that for towns in India some system of sewerage is advisable in which there is no direct continuity between the houses in the poorer quarters of the town and the sewerage system itself.

‡ And in large houses or schools, etc., *urinals*, in addition.

ing types are shown in the accompanying plate (vi).* Formerly they were made of metal and were surrounded by a wooden casing, but in the most modern closets all parts are made of china or earthenware and the wooden casing is done away with, thus ensuring greater cleanliness and the easier detection of any defects. Such a closet, as the 'Unitas' shown in the illustration, consists essentially of a basin or receiver placed directly under the seat, into which the excreta are passed and which leads directly to the second portion. This is usually an ordinary siphon trap as described in the next paragraph. After use, by an automatic arrangement, or by pulling a plug or handle, a regulated amount of water from a small flush tank or cistern overhead is discharged into the basin with considerable force, either as a jet of water or as a flush from perforations round the rim of the closet. In some closets, as the 'Carmichael,' there is both a jet and a rim flush. The contents of the basin are thereby driven into the trap and from there they pass down the pipe leading from the trap. When the flow of water ceases, the excreta have disappeared entirely and the basin and trap are full of clean water. Three to four gallons of water are necessary to flush the closet properly. In the case of baths and sinks the discharge opening or outlet leads directly into a siphon trap. All the above points are illustrated in the annexed plates. It is to be noted especially that the cistern for supplying water to the closet must be quite distinct from the general water supply of the house and, if the intermittent method of water supply† is in use, special precautions must be taken to avoid contamination of the drinking-water cistern by leakage from a closet placed over it in an upper storey of the house.

Traps.—Originally, the pipes for carrying off waste water of any kind opened directly into the bath, sink or closet at one end and into the sewer at the other end.

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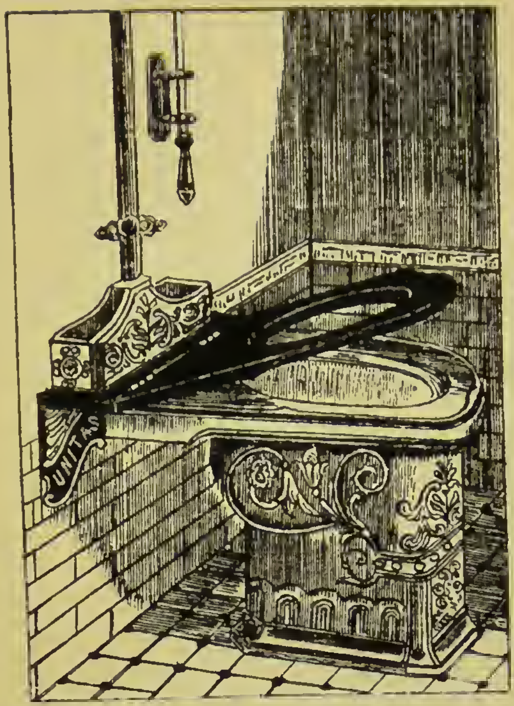
* In connection with a wet system of removal of excreta a very useful form of closet for the poorer class of houses is the *trough* closet, *v. post.* Sanitation of Towns.

† *v.* p. 57.

Plate VI.



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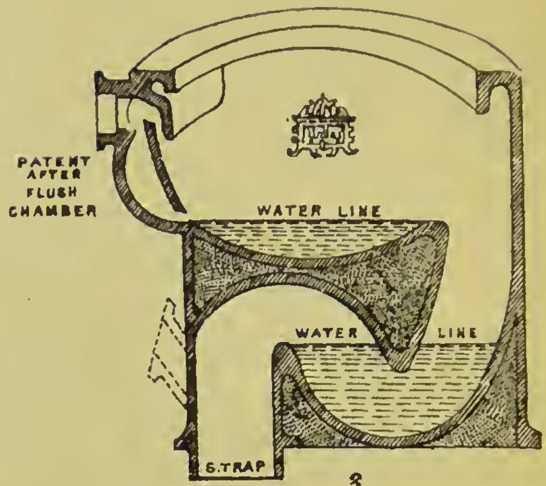

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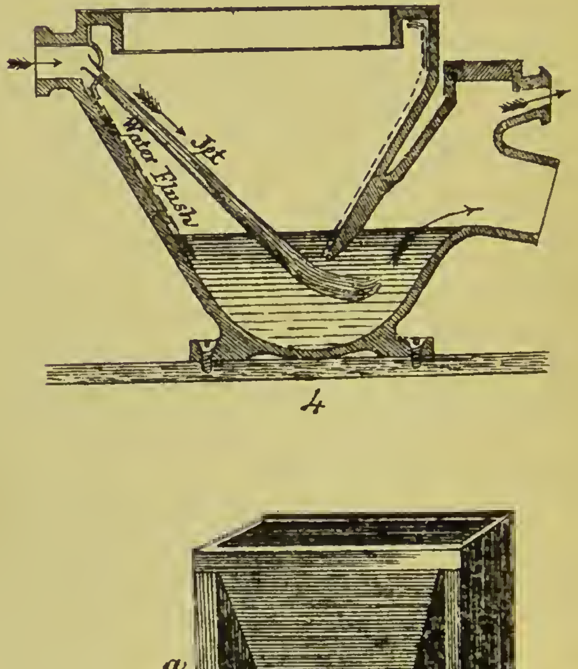

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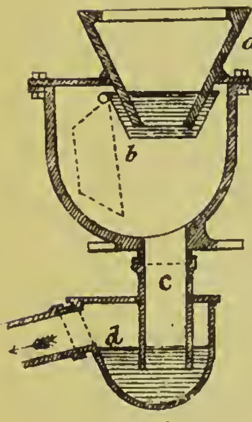

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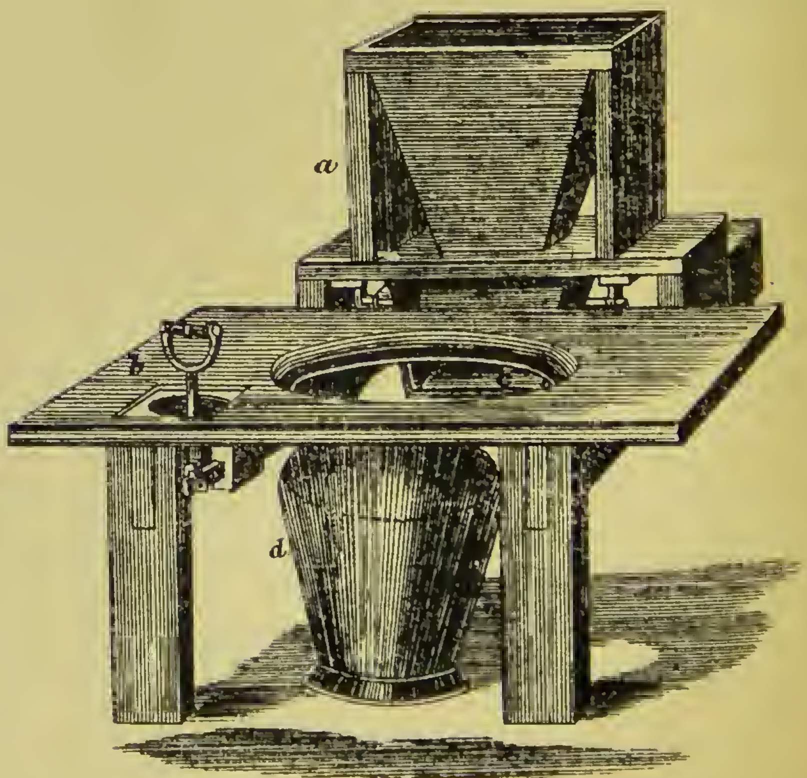

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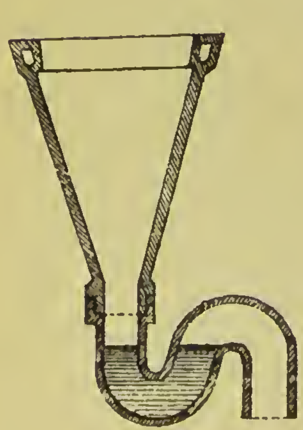

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G. PACZENSKY LITH:

To face p. 154.

PLATE VI.

CLOSETS.

Figure 1. Diagram of 'Pan' Closet with D-Trap attached: formerly in almost universal use in Great Britain, and by no means extinct yet. *a*. The Basin, which is closed (?) by a shallow metal Pan containing a little water. When the Plug or Handle is raised, after use of the closet, the excreta fall into the Receptacle or 'Container' *b*. which is quite useless and soon becomes fouled. From this the water and excreta pass into *d*. a D-Trap connected with the soil pipe, as indicated by the arrow. This form of closet and trap are both thoroughly defective and their use should be entirely prohibited. (*v*. also pl. vii, fig. 1.)

Figure 2. Diagram of 'Long Hopper' Closet with Siphon-Trap attached. It is a simple form of closet, which requires, however, a powerful flush of water after use: in addition to which the basin, from its narrow shape, is certain to become fouled, and requires frequent cleaning. An improved form, is the Short Hopper Closet, in which the cone is shorter, has a rim flush, and the back is nearly vertical, so that the excreta fall directly into the water.

Figure 3. (*a*) Twyford's 'Unitas' Wash-Out Closet: (*b*) same in section. A good representative of the modern type of closet, in which the only part made of wood is the hinged seat. This latter can be lifted at will when any vessel is emptied into the closet or when it is used as an urinal. The whole closet can be easily and quickly inspected since it is not boxed in with a wooden casing. In (*a*) is shewn the handle communicating with the flushing cistern, which when pulled causes the latter to discharge three or four gallons of clean water into the closet, whereby every thing is carried down the soil pipe: only enough clean water being retained to fill the receptacle and seal the siphon-trap, as shewn in (*b*). At the lower part of (*b*) is indicated the air pipe situated on the *distal* side of the trap, and which opens into the ventilating pipe carried up 'full bore' beyond the ridge of the roof. (*v*. pp. 157—8, and plate viii.)

Figure 4. Diagram of Buchan's 'Carmichael' Wash-Down Closet, consisting of one piece (closet and trap combined), and with the trap in the form of a P-Trap (a modification of the S-Trap). It will be observed that it possesses a *double flush* of water to ensure speedy and complete emptying of its contents. The upper right-hand arrow indicates the Ventilating Pipe on the *distal* side of the trap (as in fig. 3, (*b*)); the lower arrow the entrance to the soil pipe.

Figure 5. Moule's Earth-Closet—*a*. Dry Earth Box, *b*. Handle or Plug which, when lifted, causes the discharge of a regulated quantity of dry earth from the mouth of the hopper (*c*) into the Pail or Receptacle (*d*). The latter, when full, is removed and emptied. (*v*. p. 139).

This, however, was found to be both dangerous and obnoxious on account of the constant backward passage of sewer gas from the sewers into the pipes and ultimately into the house, thereby poisoning the air of the rooms. To what an extent this can occur is easily realised by travellers on the continent where the closets frequently open directly into a straight drain or tube terminating in a cess-pool at the bottom of the house.* Accordingly, it has become the custom to insert a Trap of some description between the original receptacle and the pipe, and between the pipe and its opening into the sewer. The principle of these traps is the same in all cases, *viz.*, the interposing of an efficient barrier to the backward passage of sewer gas whilst the onward flow of waste water into the sewer is unimpeded. This result is obtained by means of a *water-seal*,† *i.e.*, the last portion of the water which flows away is retained at a certain point and forms the barrier above alluded to. The original traps were all exceedingly defective and as a matter of fact the ideal or perfect trap has yet to be invented.‡ Various traps which have been given up as obsolete by all modern sanitarians are shown and explained in the illustrations: unfortunately, many of them are still in common use. They have nearly all two faults in common—the water-seal is too shallow and is liable to become dried up, and they are apt to retain the heavier matters in the sewage, which form a foul and evil smelling mass at the bottom of the trap, from which offensive and, it may be, dangerous emanations are given off and pass back into the dwelling.

With the exception of certain traps for special use, all modern traps are made on the principle of the siphon or

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* As also in many two-storied native houses in this country.

† Certain traps are constructed by interposing a sheet of metal or a ball of metal at the beginning or end of a pipe, so regulated that the mouth of the pipe is kept closed save when waste water is running down the pipe. They are not a good form of trap and require no further notice here. In one form of trap the siphon trap is combined with a ball trap made of India-rubber or wood, *v.* Plumbing by W. P. Buchan, p. 231.

‡ As also the 'perfect' ventilating cowl, *v.* note, p. 40.

ꭥ-trap. Of this there are many modifications, one of the best known being Buchan's trap (*v.* pl. vii.) In reality they are not siphons at all but simply pipes "bent in such a way that there is always a water-seal between the inlet and the outlet."* If properly fitted and carefully looked after they are valuable adjuncts to a good system of house sewerage, but *they must not be looked upon as perfect preventives of all danger from sewer gas.*† As will be seen later on, in a good sewerage system there should be very little sewer gas present at all in the sewers‡ and it is quite *possible* that some day traps will be found to be unnecessary.

There are one or two points which require especial attention. If a pipe is too seldom used the water in the trap will evaporate, the trap becoming 'unsealed' and useless for the time being. Again, if the trap is too small in calibre, especially if there is a sudden drop in the pipe below the trap, the waste water as it rushes through the pipe fills the latter entirely so that it 'runs full' as it is called; the consequence is that all the water is sucked out of the trap and the latter is left empty. The same thing may happen where there are several siphon traps situated at different levels but connected with the same pipe. As a rush of water takes place down the pipe the latter is completely filled (runs full) and the lower traps are unsealed in turn as the water flows past them. Both these accidents are preventible by proper ventilation on either side of the traps. Some have even supposed that a trap may become unsealed by the backward pressure of sewer air combined with the aspirating effect of the warm house-air: it is at least doubtful if such an accident ever does occur. Below every bath, sink and closet, as before stated, a trap is securely fixed, and from its lower end begins the house pipe. The traps are most frequently made of lead on account of convenience,

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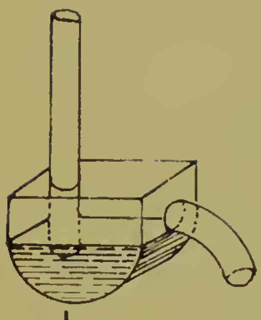
* S. and M., *op. cit.*, p. 769.

† Even the siphon trap, which is so generally suitable in a temperate climate, has been found by experience to be unsuitable in many cases in a tropical climate. *v. post.* Sewerage of large towns in India.

‡ *v.* Ventilation of sewers.

LONDON SCHOOL OF
LIBRARY

PLATE VII.



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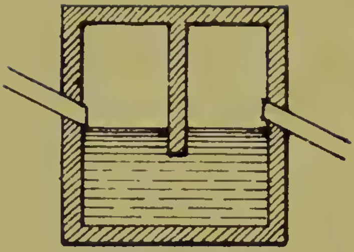

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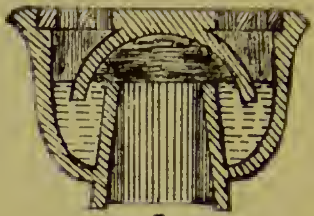

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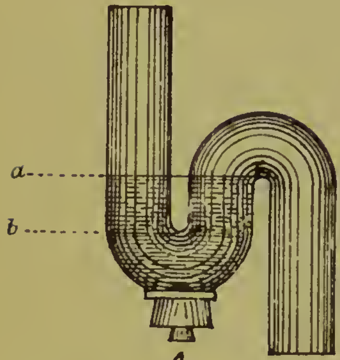

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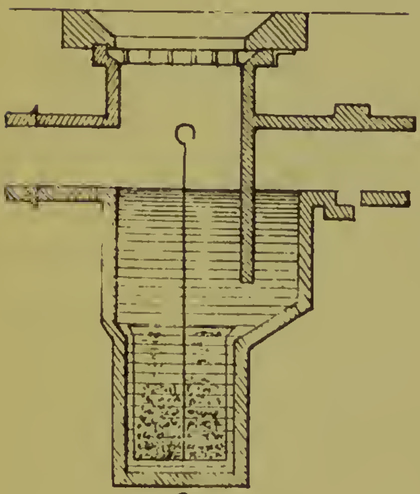

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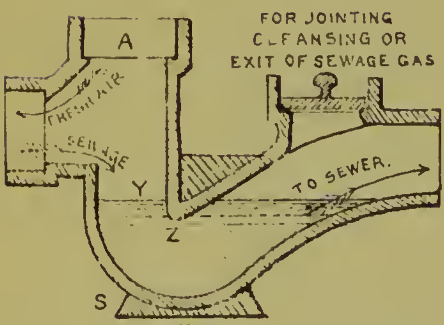

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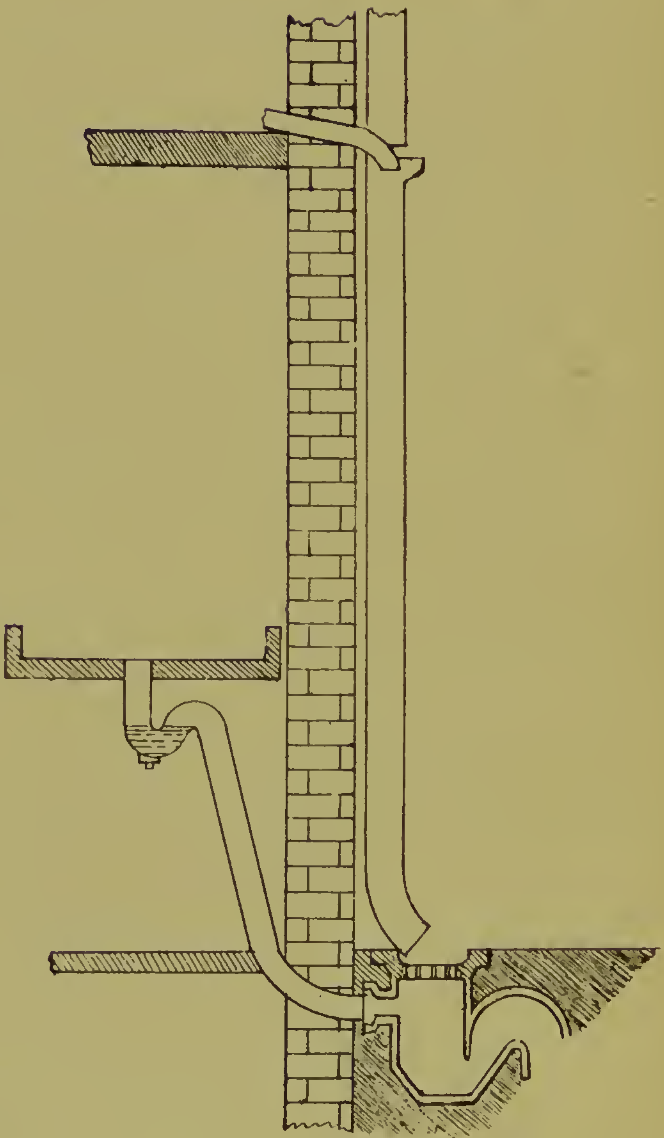

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LITH: BY ROSS, BROS.

To face p. 156.

PLATE VII.

TRAPS.

Figure 1. D-Trap, an obsolete form. It soon becomes fouled from the deposit of solid matters, and cannot be flushed properly.

Figure 2. Dip-Trap, an obsolete form. The tongue is made of stone or metal. If not in constant use it becomes 'unsealed' from evaporation of the water, and it cannot be flushed properly owing to its rectangular shape.

Figure 3. Bell-Trap, an obsolete form. The top is removable for inspection, but it is certain not to be inspected sufficiently often. In addition it is liable to become choked, and the water seal soon evaporates if the trap is not frequently flushed.

Figure 4. S-Trap or Siphon trap, with removable screw plug for cleaning purposes. The depth of water between *a* and *b* constitutes the 'seal' of the trap, and is considerable in this case. In some cases a smaller seal is advisable (*v.* fig. 5).

Figure 5. Buchan's Patent Disconnecting Ventilating Siphon-Trap. It is a simple and effective form of trap. The 'water seal' *i.e.*, the dip of the tongue (Z) below the surface of the water is 1″·5. Owing to the drop of 2″ which the water gets in flowing from the drain branch (W) into the well (Y) of the trap, it washes out the contents completely, instead of flowing *under* the floating matter as in the old fashioned Siphon. (For trap in position *v.* pl. viii.)

Figure 6. Dean's Gully Trap. It is really a modified dip-trap and is only intended for waste water from kitchens, backyards, etc. It contains a bucket with a handle, into which stones, etc., fall, and which is removed and emptied at intervals. (Gully traps are shown at fig. 7 and at pl. viii., D. *q.v.*)

Figur 7. Disconnection of Combined Rain and Waste Water Pipe over Siphon Yard Gully. [After L. Parkes.] In this case the rain water pipe is utilised as the waste pipe as well. The basement waste pipe discharges into the gully by a special side inlet, the upper waste pipes into the open head of the rain water pipe at each storey of the house. Here the rain water pipe, which is carried 'full bore' above the roof, acts as ventilating pipe to the branch waste pipes, while it discharges its contents on to the iron grating of the gully. The above arrangement is quite distinct from the soil pipe (for which *v.* pl. viii.) It is not an arrangement to be commended, for the waste water fouls the rain pipe with grease, etc., and gives rise to offensive smells which penetrate into the house through the windows. The proper plan is to keep soil pipe, waste pipe, and rain pipe quite distinct.

but in other cases, *e.g.*, water-closets, they are usually of porcelain or coated cast iron.

House or *Sullage Pipes.*—Under the above heading only those pipes carrying waste or sullage water are included here, though of course there are several other sets of pipes in most English houses, for carrying water, gas, etc., with which we have no concern here. The former are often called the *waste pipes* and the latter the *soil pipes*. Careful distinction is made in modern houses between the pipes for conveying waste water from baths and sinks and the pipes which carry only the sewage water from the closets, and the two systems are kept quite separate, though the ultimate destination of their contents is the same. Soil pipes are either made of drawn lead or of iron (cast iron or galvanized iron—never wrought iron). Great care must be taken in fitting the various lengths of the iron pipes and they should be coated internally and externally with pitch or Angus Smith's preparation or by Barff's process.* The pipes are usually carried outside the house, one set for waste water and the other for sewage water from the closets, as explained above. They do not open directly into the house drains.† The waste pipes are made to discharge into the *open air* and this result is frequently brought about by making them open into the rain water pipe as it passes down the outer wall of the house. The rain water pipe is disconnected from the drain below by opening on the grating over a siphon trap leading to the drain (*v.* pl. vii). If a separate waste pipe is carried down the outer wall of the house it is made to end in the same way, *i.e.*, over a trap, and is carried up full bore above the ridge of the roof, its end being left open or covered with netting. The soil pipes themselves are brought down *outside* or inside the house, the former being the more usual, but they always end in one way, *viz.*, by opening directly into a

* *v.* p. 76.

† The term house drain as used in this and the following para., is applied to the commencement of the sewerage system *outside* the house. It is in reality a small sewer.

siphon disconnecting trap (*v.* pl. vii). The soil pipe itself is always carried up full bore to the top of the house above the ridge of the roof, its top being left open or covered with a ventilating cowl (*v.* pl. viii). The sizes of these pipes vary under different arrangements: as a rule, the soil pipes have an internal diameter of about four inches, the waste pipes one-and-a-half to two inches. Very many other details have to be attended to with regard to the house pipes which it is unnecessary to further allude to here.

House Drains.—These may be looked upon as the feeders of the small sewers which run down the middle of the streets between the rows of houses. Between the waste and soil pipes of the house and the house drain is placed a disconnecting, ventilating siphon trap, as mentioned before, so that the house drain starts at the distal end of the trap. In most cases, where there are special waste pipes distinct from the rain water pipes these house drains receive only the waste water and water closet sewage, the rain water from the roofs and ground surface being conveyed away separately. The drain is usually constructed of two-foot lengths of circular pipes made of glazed stoneware, which are very carefully jointed together with cement of various kinds. The drain should be laid perfectly straight so as to be open from end to end for inspection and its interior should be quite smooth and free from obstructions of all sorts. If the soil is loose and sandy, cast iron coated pipes are preferable, or the stoneware drains may be laid in a thick bed of concrete. In Germany cement and silicated concrete pipes are extensively used and are said to be less brittle, more capable of withstanding extremes of climate and of resisting the chemical action of sewage, to improve with age and to withstand the jarring effect of heavy traffic overhead.* The pipes vary in size from four to nine inches in diameter according to the size of the house they drain.

* These pipes would probably be very suitable for use in India. The author of Sanitary Engineering in India, Mr. John Wallace, C.E., Bombay, is a strong advocate for the use of iron pipes for the removal of sewage, as in the Shone and Berlier systems (*q. v.*), in India.

PLATE VIII.

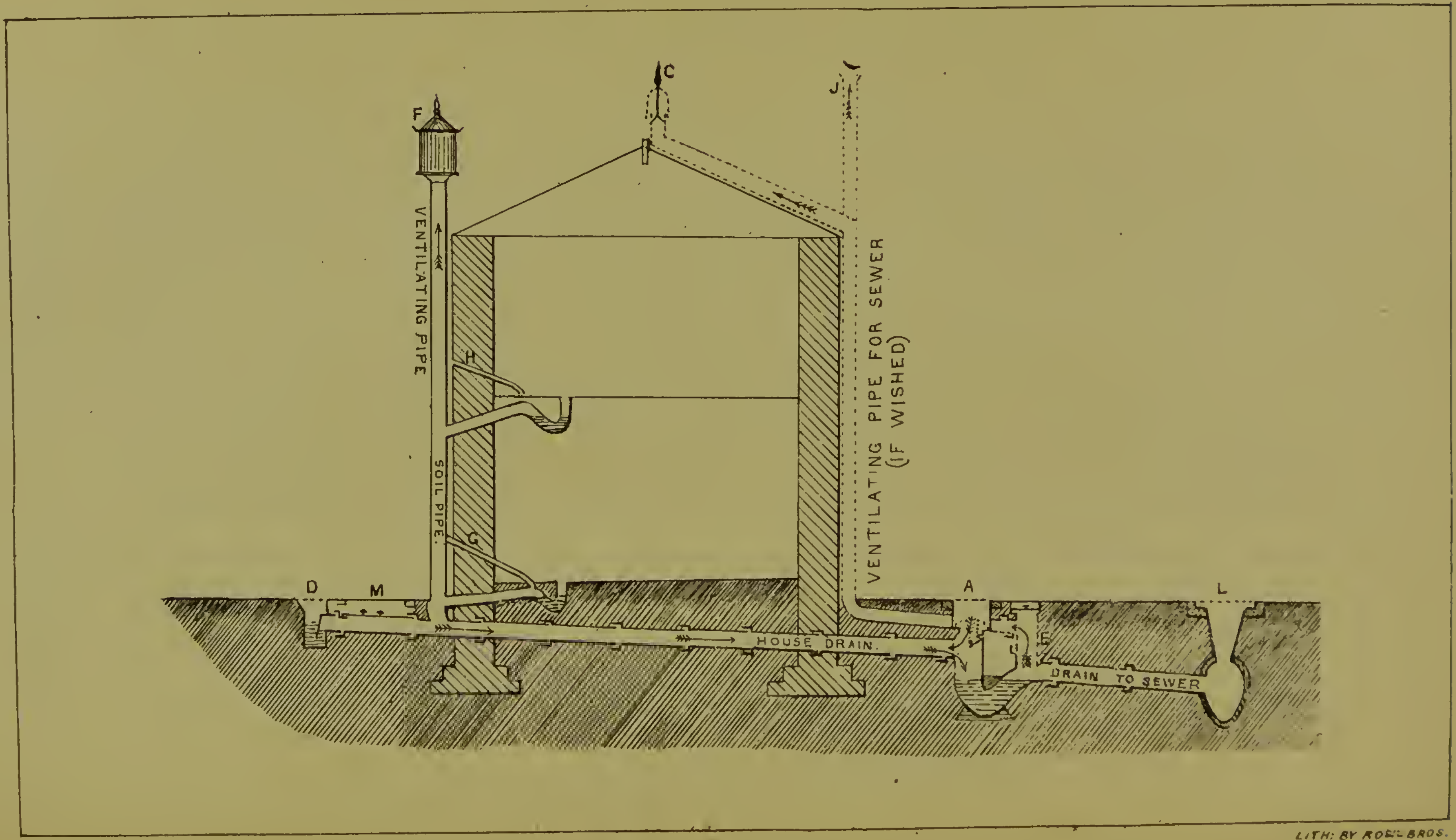

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PLATE VIII.

HOUSE DRAINAGE.

Vertical Section of a House, showing the arrangements adopted for house drainage in connection with a modern sewerage system (after W. P. Buchan).

[NOTE.—The house drain is here shown passing *under* the house, an arrangement only permissible when absolutely necessary, as in crowded parts of towns, etc., (*v.* pp. 158-9). Note, also, that in this case there is no waste water pipe shown distinct from the soil pipe; that the soil pipe leads directly into the house drain; that there is only one disconnecting and ventilating trap between the house and the sewer; and finally, that here the 'drain to sewer' is what is usually designated the 'house drain'—*i.e.*, in those cases where the soil pipes and waste pipes are trapped as described in the text (*v.* Summary, p. 168)].

D. Gully Trap (*v.* figs. 6, 7, pl. vii..) M. Inspection Manhole. G. and H. Ventilating Pipes carried from the crowns of the siphon-traps and opening into the soil pipe, which latter is carried up 'full bore' above the ridge of the roof and ends in a Fixed Cowl, F., for ensuring an up-draught. The house drain is shown opening into a Buchan's trap (*v.* fig. 5, pl. vii.). At A. is a Perforated Grating which allows of fresh air entering the house drain, passing along the latter and up the soil pipe, to be discharged at F., carrying with it any foul air in the house drain or in the soil pipe. The Ventilating Pipe shewn in dotted section, and which is intended to ventilate the 'drain to sewer' beyond the Buchan's trap, may be used when there is a danger of sewer gas forcing itself by pressure past the dip or tongue of the siphon-trap. The foul air may be arranged to discharge at J. or at C. as desired. L. Manhole, and Ventilator (if desired), for the street sewer.

[NOTE.—Many other arrangements of the house drainage are possible, and even advisable, but are too complicated for the present purpose. For these, special works must be consulted].

The drain *should not pass under the house* unless absolutely necessary (as shown in illustration); where it does do so there must be inspecting manholes placed at intervals on the drain so that it can be opened and thoroughly examined if possible. In such a case if the house drains are badly laid or if the joints are not air and water-tight there is great risk of poisoning of the occupants of the house by sewer-gas.*

Sewers.—The house drains lead the sewage into the *street drains* or *tributary sewers*, but should not do so directly, as is still frequently the case. There should be efficient disconnection by some suitable form of trap which prevents backward passage of sewer-gas, provides for ventilation and allows of thorough inspection and cleaning. The smaller sewers are sometimes made of circular pipes of much the same kind as the house drains, only larger; the same precautions in laying and construction are necessary. These smaller sewers open into larger ones, the *mains*, and these again into the *outfall sewer*.†

It will be seen that under this 'separate' system, as it is called, only waste water and sewage with *possibly* the surface water from the immediate neighbourhood of the houses is permitted to enter the sewers. The latter are therefore made air and water-tight and of small size. Special provision must be made for the carrying off of rain-water and for the drainage of the subsoil, a very important point, particularly where the subsoil is so completely filth-sodden as it is in Indian towns. There are several ways of doing this which may be mentioned here. (1) If the town possesses an old system of brick drains and sewers, which are porous and therefore permit the subsoil water to enter them from without, they can be utilised for collecting the rain

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* For much useful information on this and kindred subjects, *v.* Mr. Pridgin Teale's pictorial guide—Dangers to Health.

† Under this system the only sewers made of brick are the mains (in large towns) and the outfall sewer. Their construction is explained afterwards, *v.* p. 161.

and subsoil water and the main sewer can be directed to the nearest river or other outlet without fear of harm. (2) The combined drain and subsoil pipe known as Brooke's may be used. The drain or pipe carrying the sewage rests upon an invert block under which is a ⌓-shaped subsoil pipe for draining the soil (*v.* pl. x). (3) The pipe sewer is laid as usual and over this are laid open-jointed agricultural tile drains, surrounded with gravel, into which the subsoil water flows and is carried to any convenient outlet apart from the sewage.

This plan of separating the sewage from the rain and subsoil water is comparatively modern. Sewers as originally constructed were "underground channels destined to receive and convey away by gravitation the rainfall and waste waters of the town."* At a later period the overflow from cesspits and middent was allowed to enter them, and finally, when the water carriage system of excreta became general, the whole sewage of the town was received by them—such a method being known as the 'combined' system. It is not necessary here to go into any details regarding the original construction of such a combined drainage and sewerage system. Suffice it to say that it is practically obsolete and that the discredit into which the practice of the removal of excreta by water carriage at one time fell was largely due to the rash attempt to make one set of drains perform two radically different functions. The relative advantages and disadvantages of the separate system as compared with the combined may be thus stated :—

(1) Under the separate system the *total volume of sewage is very much less*, from which it follows that the sewers need not be made of such an enormous size as under the combined system and, in addition, the sewage is more easily disposed of.†

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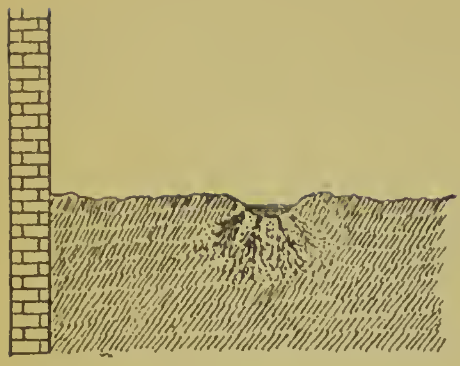
* E. A. Parkes, Hyg. and Pub. Health, 2nd ed., p. 149.

† *E.g.*, the two towns of Romford and Slough, near London, with same population and same amount of water-supply per head. The sewage farm at the former received in one year over 100,000,000 gallons of

Plate IX.



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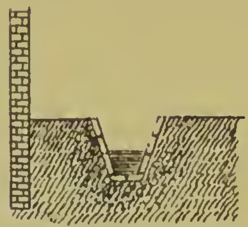

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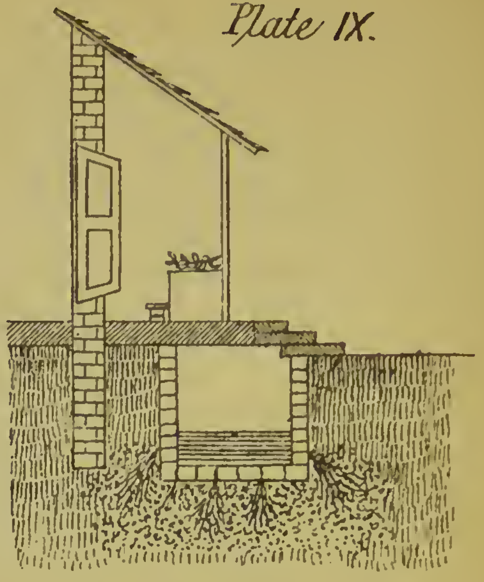

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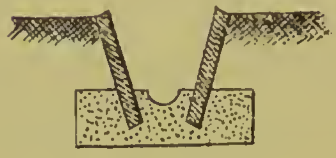

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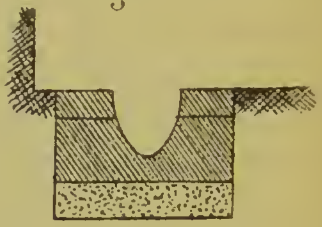

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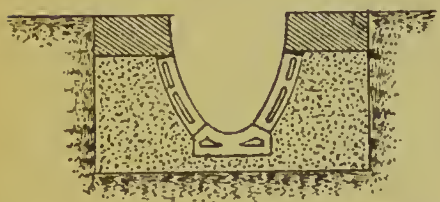

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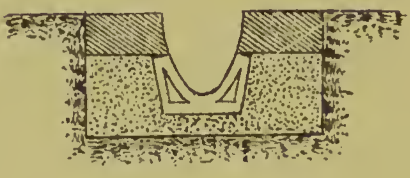

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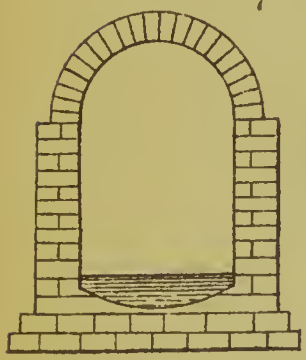

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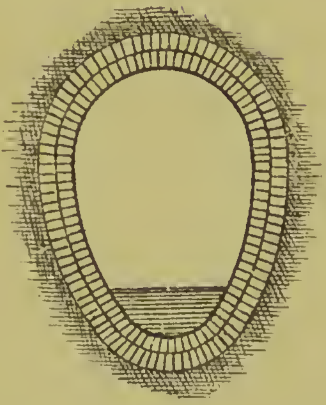

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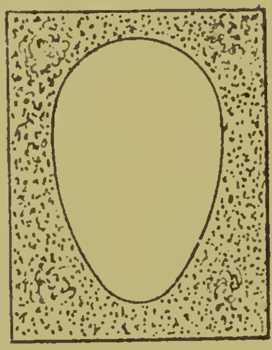

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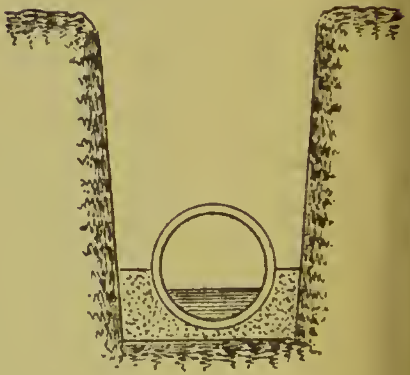

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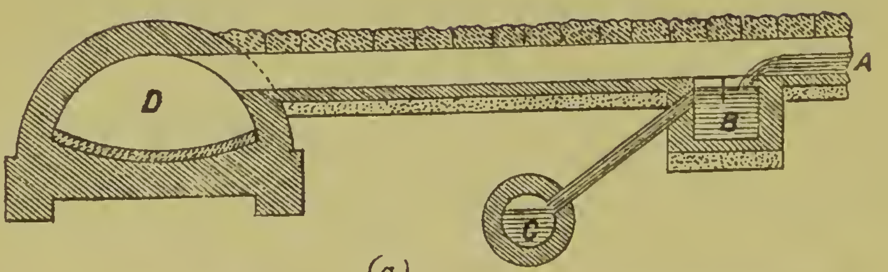

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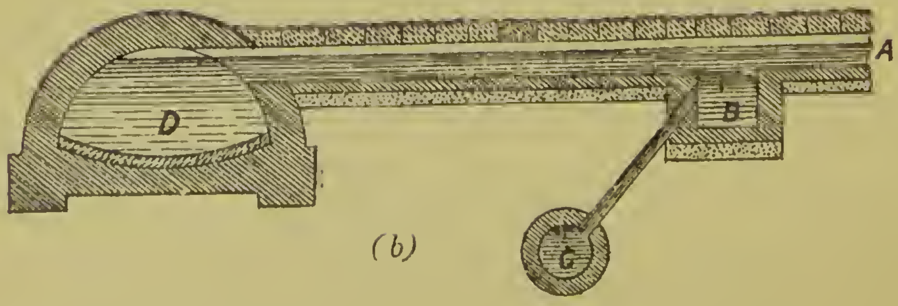

(b)

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PLATE IX.

DRAINS AND SEWERS.

Figure 1. Rudimentary form of Drain made by scraping a channel in the soil. (*v.* pp. 148-9, 179).

Figure 2. Flat Bottomed Drain formed of slabs of stone or of bricks set in mortar.

Figure 3. Rectangular Drain, of large size, built of country bricks. Such drains are commonly seen running along the side of a street, in immediate proximity to houses, shops, etc.

Figures 4, 5, 6. Improved Drains for use in India, made of slabs of stone set in concrete, or of cement (after A. M. Jones.)

Figures 7, 8. Improved Drains (designed by Jennings of London from suggestions by Surgeon-Major W. G. King, I.M.S.) The essential point is the use of accurately made bricks of glazed fire clay, either in three pieces (fig. 7), or in one piece (fig. 8), which can be rapidly laid 'true' by unpractised workmen: whereas the accurate construction of the ordinary drain (*e.g.* fig. 4) requires considerable skill and experience. They are not expensive.

Figures 9, 10, 11. Sewers, shown in section. 9. Obsolete form of Brick Sewer. 10. Modern Egg-Shaped Brick Sewer. 11. Egg-Shaped Sewer of Concrete; for use in soft soil.

Figure 12. Stoneware Pipe Sewer in Trench, as used for house drains, etc. (*v.* also plate x). If the soil is soft or yielding the pipe should be laid in a concrete bed.

Figures 13, 14. Diagrams to illustrate the Interception System of Drainage as applied to Blacktown, Madras (after A. M. Jones). In (*a*) the ordinary condition of things is shown, where the sewage passes into the gully and from thence to the main sewer. In (*b*) is seen the condition of matters during heavy rain, shewing the branch sewer 'running full' with mingled rain water and sewage, the greater part of which passes into the old Blacktown sewer and thence to the sea or the canal, whilst the smaller portion is carried off by the main sewer to the pumping station and thence to the outfall at the sewage farms.

A. Branch sewer which collects the sewage from the open drains that run along the sides of the streets. B. Gully, into which the sewage falls and, under ordinary conditions, passes by the lower opening into the main Blacktown sewer, C. D. Obsolete Blacktown sewer which is only used for carrying off 'storm water' during heavy rain.

Whether therefore the separate or the combined system be adopted by a town, large sewers will have to be constructed; the only essential difference is that in the latter case they must be porous and of greater size. Now-a-days such sewers are nearly always made of oval shape, though occasionally the large outfall sewer is circular. It can be seen from the accompanying illustrations (*v.* pl. ix) of what varied shapes they were formerly made. The egg-shaped sewer is by far the most suitable where the volume of sewage is liable to undergo fluctuation: there is greater depth of sewage and less contact with the walls of the sewer, and hence less friction. Up to eighteen inches diameter circular sewer pipes are most convenient; above that size, egg-shaped brick sewers should be used. These may be twelve feet in diameter or more. They are constructed of well-burnt impervious bricks or glazed firebricks and the floor of the sewer is frequently made of suitably curved stoneware blocks or inverts. They are laid as far as possible in straight lines, with manholes for inspection and cleaning at every change of direction. Such a manhole is shown in section (*v.* pl. x). The gradients are very carefully laid, being uniform except at certain places, *e.g.*, when smaller sewers join the main sewer or when there is of necessity an abrupt change in the direction of the sewer. In such case the gradient is temporarily increased in steepness. As stated before, all junctions must be made in the direction of flow, *i.e.*, at acute angles, so as to offer no obstruction (*v.* pl. x). The rate of flow should ordinarily be from two to three feet per second, the gradient running from 1 ft. in 250 ft. to 1 ft. in 750 ft. according to the size of the sewer.*

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* In calculating the discharge from sewers the following formula is generally used.

$$V = 55 (\sqrt{D \times 2 F})$$

Where V = Velocity of flow in feet per minute.
D = Hydraulic mean Depth.
F = Fall in feet per mile.
If A = Sectional Area of current of fluid, V × A = discharge in cubic feet per minute. The hydraulic mean depth is the sectional area of the current of fluid divided by the wetted perimeter (that part of the

PLATE X.

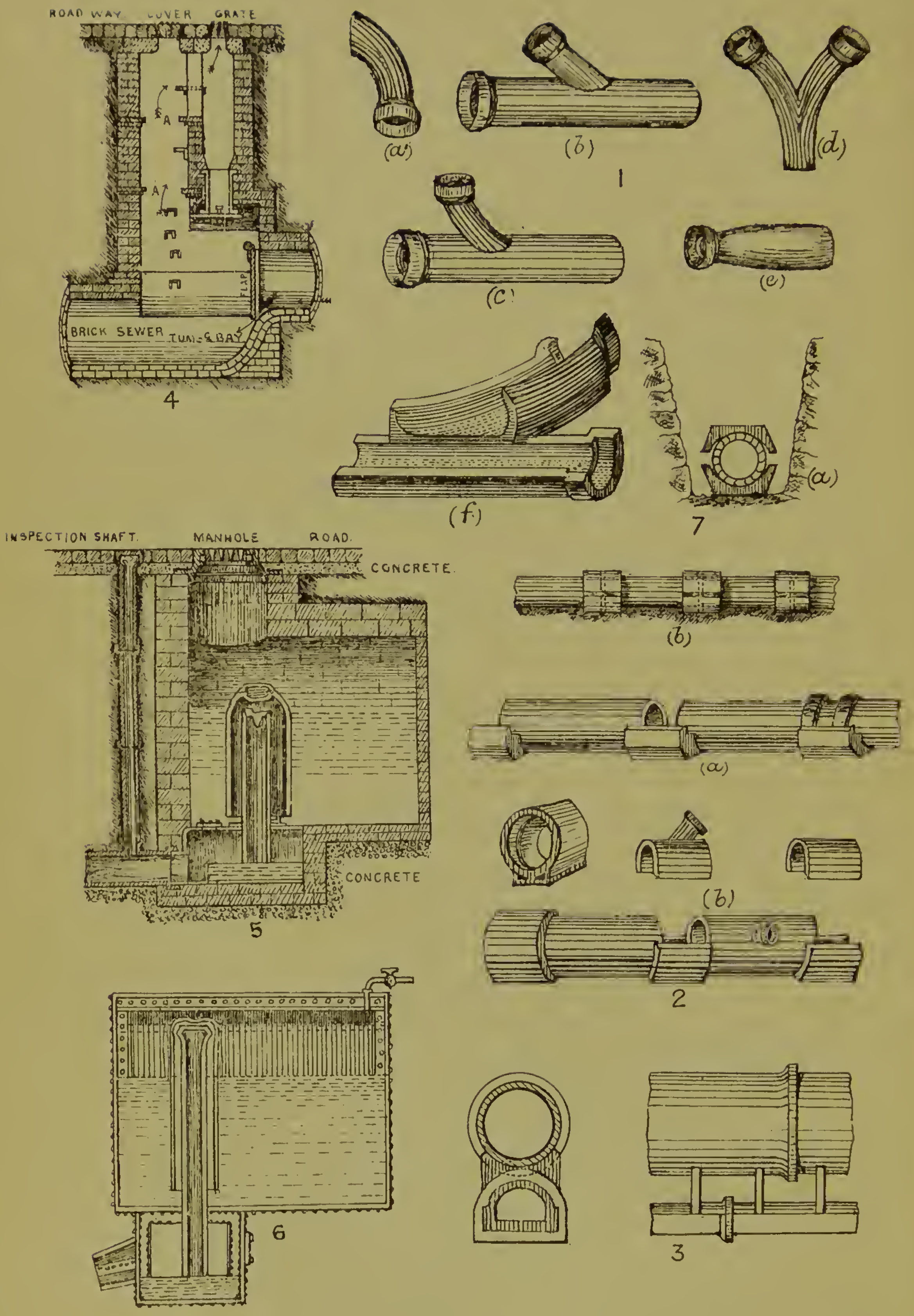

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PLATE X.

PIPES, MANHOLES, FLUSHING TANKS, Etc.

Figure 1. (*a*), (*b*), (*c*), (*d*), Various forms of 'Junction' for use in the joining of pipe sewers. (*e*) Taper-Pipe, for connecting pipes of different calibre. (*f*) Winser's Channel Bend. At the point of junction the afferent pipe has a 'straight channel', as shewn in the diagram, with a bend specially adapted for concentrating the sewage as it rises and flows round the bend.

Figure 2. Glazed Stoneware Pipes, as used for house drains, small sewers, etc., (*v*. pp. 158-9). (*a*) Patent Chair and Saddle Pipe (Geo. Jennings), (*b*) Improved Registered Drain Pipe (Stiff). Of such pipes there are very many varieties in use, the differences chiefly consisting in the methods of jointing. It is most important that the joints be absolutely air and water-tight.

Figure 3. Brooke's Patent Subsoil Drain and Pipe Rest. Above is seen the ordinary pipe for conveying sewage, resting on an invert block ; below is the subsoil drain for draining away the subsoil water.

Figure 4. Means of Ventilation and Inspection of a Brick Sewer (3′ 9″ × 2′ 6″). At certain points in the course of sewers with a steep gradient a 'Tumbling Bay' is constructed, and in connection with this there is a Manhole giving access to the sewer from the roadway, and a Ventilating Chamber opening on to the street by a grating. The 'Flap Valve' allows the sewage to flow into the tumbling bay, but prevents the backward passage of sewage or sewer air to the higher levels of the sewer and compels the air to rise and escape at the ventilatory grating. The horizontal line indicates 'higher water level' in the sewer. (After Rawlinson—reduced and slightly modified.)

Figure 5. Large Automatic Siphon Flushing Tank or Cistern for scouring sewers, etc. (Rogers Field). The principle of these tanks is that of a siphon in which the long arm is placed within the short arm. The long arm dips into a small amount of water (retained in position by a weir). As the tank fills, the water rises at the same rate in the short arm and when it reaches the level indicated in the diagram it is directed, by means of a projecting lip, to the centre of the siphon, so that in its fall it carries with it sufficient air to create a partial vacuum and start the siphon action. [Note.—In this figure, the broken shading indicating water should be continued to the bottom of the tank as in fig. 6.]

Figure 6. Small Automatic Siphon Flushing Cistern for use with water-closets, etc. Here the action is automatic; in other cases the action is started by pulling a handle, as shown in plate vi. fig. 3 (*a*). In both cases a *definite* amount of water, usually 3 or 4 gallons is discharged, and the closet, etc., properly flushed, but *without waste* of water. [NOTE.—These flushing tanks (figs. 5 & 6) can be made of any desired capacity and their rate of filling regulated to a nicety by the tap that fills them, (shewn in fig. 6). Thus they can be made to discharge every five minutes or once in twenty-four hours, and so on. The siphon is easily accessible for cleaning, etc. The tank shown in fig. 5, is much larger than that in fig 6 but is reduced here for convenience.]

Supposing then that a good system of sewers has been built, the following things must be carefully attended to, *viz.*, Inspection, Cleaning, Flushing and Ventilation. In the original badly-constructed sewers once they were brought into use they formed practically an underground series of tunnels unevenly laid, with rough interior walls, only accessible by breaking open the crown of the sewer, and never properly cleaned.* In a modern sewer the construction and means of inspection, as before noted, are such that these evils have been almost entirely done away with. From end to end they can be inspected and if from any cause partial or complete chokage (very rare) should occur, the obstruction can easily be removed.† Periodic flushing by means of a rush of water is extremely useful. This was formerly done by playing a hose attached to the water-main into the sewer or by damming up the sewage for a certain time and then allowing it to rush forward suddenly. Now the same result is achieved much more thoroughly by means of automatic siphon flush tanks (*v.* pl. x) placed at 'dead-ends,' *i.e.*, the commencement of the branch sewers, or any other convenient spot. These tanks discharge their contents of one or two hundred gallons automatically, at intervals regulated by the supply pipe to the tank, and produce a most effective scouring action on the sewers. Very small sewers can be scoured by simply emptying an ordinary water-cart into a manhole, as is done in this country.

The ventilation of sewers is an extremely important

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circumference of the sewer wetted by the fluid flowing through it); in circular sewers it is constant and equal to one-fourth the diameter. For simple explanation of hydraulic mean depth, etc., *v.* Jones' Manual, p. 168.

* The cost of removing deposits from the former stagnant sewers in London amounted to £30,000 or 3 lakhs of rupees *per annum.* Sir J. Bazalgette—quoted by S. and M., p. 837.

† The chokage in pipe sewers generally arises from one or more of the following causes:—(1) Improper gradients. (2) Insufficient flush. (3) Foreign articles finding their way into and choking the sewer. (4) Defective joints through which the liquid runs, leaving solid matters behind. (5) An excess of road detritus or ashes finding their way into the sewer. (6) Improper bends in the line of sewer. (7) Right angle or improper junctions being formed with the sewer. (8) A collapse of the sewer. *v.* Boulnois *op. cit.*, p. 296.

thing but is hardly yet understood.* "To know that the infective agents of such diseases as cholera, typhoid fever, many cases of diarrhœa, and probably other diseases, are passed out of the body in the excretions of the patients suffering from them, that they probably have the power of self-multiplication outside the body in sewers and sewer deposits, and can infect the air in contact with them, is to understand the importance which sewer ventilation has in relation to public health, and to impress the necessity for the closest attention to this subject on the part of those who are entrusted with local sanitary administration."† A large amount of sickness and disease has been proved to be due to defective sewerage systems in Great Britain, so much so that many who have not followed the subject closely or who have been absent from that country for many years are still persuaded that these evils are as great as they formerly were. This, of course, is not the case, and it may be confidently stated that in a modern well-sewered house connected with a good separate system of sewerage the dangers are reduced to a minimum and are far less than they were in the days of privies and cesspits, of shallow, porous drains for the nominal removal of waste water, of heaps of decomposing food refuse and general rubbish in the immediate neighbourhood of each house.

The various theories which have been held in connection with the movement of air in sewers and the various means adopted to ventilate the latter are foreign to the scope of the present work. Suffice it to give a few plain statements. Firstly, as regards the movements of the air in sewers. These are *extremely irregular and their direction depends on many factors, e.g.*, the relation of the temperature of the air inside the sewers to that of the external atmosphere, the direction and strength of the prevailing

* "The whole subject of scientific and sanitary sewer ventilation is beset with difficulties," (Boulnois, 1892). If this is true in England with years of experience, how much truer is it in India!

† S. and M., *op. cit.*, p. 839.

wind,* the steepness of the sewer gradient, etc. Formerly it was customary in manufacturing towns to discharge the waste steam or hot water from different works into the sewers, thus hastening the decomposition of the sewage and setting up strong currents in the sewer air. This is now forbidden by law.

As regards remedies the most generally applicable one is the leading of a shaft from the crown of the sewer to the road above, covering the opening with a grid and placing a dirt box immediately inside the opening to prevent road débris gaining access to the sewer. They are generally placed at intervals of about one hundred to one hundred and fifty yards. Sometimes the ventilating shaft is placed alongside the manhole (*v.* pl. x). Whether the shaft acts as inlet for fresh air or as an outlet for foul air depends as above stated on many factors. It is not a perfect system, and in hot, dry weather the nuisance may be considerable to dwellers in the street along which the sewer passes. The very tall chimneys attached to chemical and other works have been utilised as sewer-ventilators but not with much success†. In sewers where the gradient is steep the foul air tends to pass from the lower to the higher levels and to accumulate at the latter places, constituting a danger to the houses in those neighbourhoods. This backward current can be prevented to a large extent by means of a tumbling-bay and flap valve placed at each combined manhole and ventilator. The sewage can flow onwards but the valve prevents anything passing backwards (*v.* pl. x). As mentioned before, the air in a good sewer is not particularly foul; in the old-fashioned brick sewers it was often extremely impure.

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* In a long series of experiments, Santo Crimp found that the wind, by its varying force and direction, was by far the most important factor in causing movements of the air in sewers.

† As also the street lamps. The object in sewer-ventilation should not be the disguising or destroying of foul odours so much as their prevention by means of cleanly sewers and plenty fresh air.—It is desirable also to equalise the pressure inside and outside the sewer, as nearly as may be, to prevent the escape of sewer gas through the water seals of the traps. (Wallace.)

The sewage is now removed so quickly and there is so little deposit in the sewers that before decomposition has advanced much the sewage has left the sewers and been disposed of. Of course, as in the case of the air of a dwelling room, the chemical composition of the air forms no trustworthy guide to the quality of its biological or living impurities, still, as a general rule, the purer the air the less likely is it to be laden with dangerous organic impurities. It is probably only in sewage which is undergoing rapid fermentation and on the surface of which bubbles are constantly bursting that numberless micro-organisms are given off, many, no doubt, harmless, but others of a distinctly pathogenic or disease-producing nature.*

Outfall Sewers.—These, as before remarked, may be ovate or circular in shape. Originally, they discharged almost without exception directly into a river or other watercourse a short distance below the town or into the sea. The former is now illegal under the Rivers Pollution Act.† If sewage has to be discharged into a river it must first be treated by some of the purifying processes to be described in the next section, so that the effluent, *i.e.*, the water flowing away after purification, may attain to a certain standard degree of purity. In some cases the sewer has to pass across a river or valley and in such cases the

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* The scientific study of sanitary problems being practically unrecognised officially in India, no experiments of any note have been made in connection with the subject of sewer-ventilation. The result is that in Bombay, where the air in the sewers is extremely foul, there have been numerous deaths amongst the sewer men, when working in the sewers. Great precautions are now taken to prevent the occurrence of such accidents. The conditions in this country are in many ways different from those in a temperate climate. (*v. post.* System of Refuse Removal Suitable for India). "The quality of the sewage varies in different districts of Bombay, according to the prevailing style of diet used by the inhabitants. Hindus, whose diet is fish, rice and vegetables, produce, in the refuse of cooked and uncooked fish, rice water and other vegetable remains, an exceedingly foul smelling sewage ; and the sewers of the quarters inhabited principally by them are said to be unusually foul." Wallace, San. Engineering in India, p. 96. Properly conducted experiments, by trained and capable men, on sewer-ventilation, under official recognition and sanction, are urgently required.

† *v.* Disposal of sewage.

outfall is generally at too low a level to admit of bridging. This difficulty is got over by laying the sewer, in the form of an inverted siphon, in the bed of the river or valley, a ventilating pipe being attached to the descending arm of the siphon in order to allow of the escape of air which might interfere with the siphon action.

When the outfall is into the sea directly or into a tidal river it is necessary to have tanks wherein the sewage can be stored until the commencement of the tidal ebb. If the outfall is carried directly into the sea great trouble and nuisance is apt to be caused at certain seasons by the rush of the tide into the sewers whereby the sewage may be carried back a considerable distance and even flood the ground floors of houses situated at a low level.* In any case, stagnation with resulting deposit and decomposition is very apt to take place in outfall sewers and great trouble must be taken to prevent such an occurrence. The position of the outfall must be such as not to give rise to any nuisance.

Summary.—Such then is the construction of a modern sewerage system on the 'partially-separate' system as it is called, *i.e.*, where the sewage at the outfall consists of *waste water, excreta and a small portion of the ordinary rainfall* from the roof and immediate neighbourhood of the houses, but does *not* include the larger portion of the rainfall nor any subsoil water. The details of such a system may be summarised as follows :—

(1) *Baths, sinks* (and *basins*) for the reception of ordinary waste water.

Water-closets (and *urinals*) ... ... liquid and solid excreta, and flushed with clean water from *special cisterns*.

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* This objectionable state of things used formerly to occur at St. Andrews on the E. Coast of Scotland. It is not likely to occur in this country as the tides are much smaller, but great trouble may arise through the sewage being carried by currents and re-deposited along the foreshore, as has happened at Bombay.

Underneath every bath, sink, water closet, etc., is a *siphon trap*. In the case of water closets the trap is ventilated. Below the traps the *house pipes* begin. Of these there are two sets—(*a*) the waste-water pipes from baths, etc., (*b*) the soil pipes from urinals and water closets. Both sets of pipes pass down the *outside* of the house, if possible, their upper ends being open and carried above the ridge of the roof for ventilation. The waste-pipes end below in the open air over a *trapped grating*, through which the waste water enters the house drain. The soil-pipe ends below in direct continuity with a *ventilating disconnecting trap*.

(2) Between the house and the sewer is placed the *house drain*, in reality a small sewer, constructed of carefully-jointed and cemented pipes. This is trapped and ventilated at both ends, is laid in a straight line, and has small manholes for inspection and cleaning. It should, if possible, be placed at the back of the house :* if it must pass underneath the house it should be made of coated cast iron. The house drain opens into a *ventilating disconnecting trap and manhole combined* which is placed at its junction with the street sewer.

(3) These *street* or *tributary sewers* join the larger or main sewers and are of the same nature as the house drains, only larger (*pipe sewers*.) They open into the *main sewers* at suitable angles. These latter are large pipes in small towns; in large towns they are brick sewers. Finally, the main sewers open into the outfall sewer which ends at some spot, situated at a suitable distance from habitations, where the sewage is disposed of. The construction of and means for inspecting, flushing, and ventilating sewers have already been described.

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* *v.* Boulnois, *op. cit.*, p. 292.

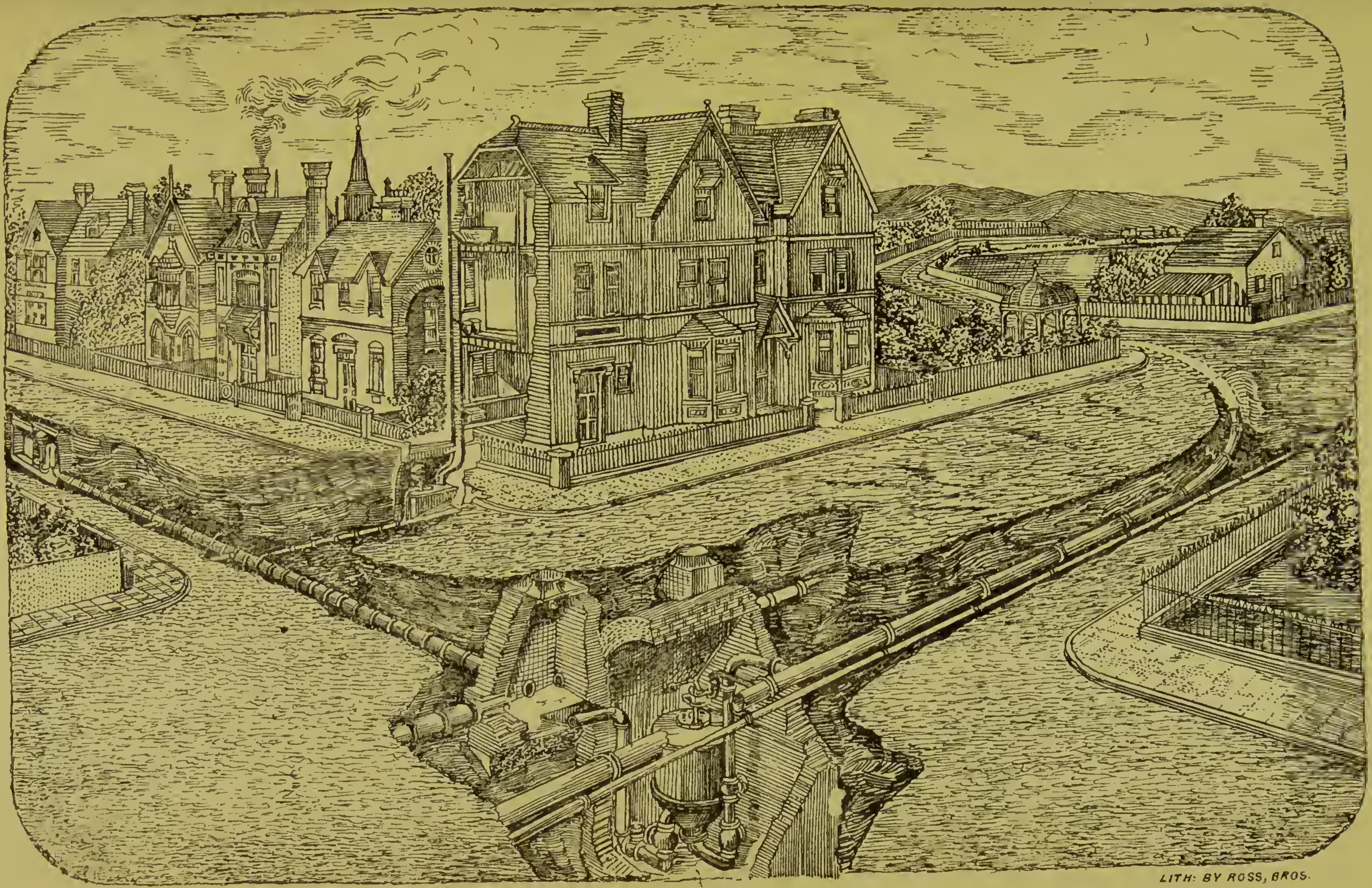
To face p. 169.

PLATE XI.

THE HYDRO-PNEUMATIC SYSTEM OF SEWERAGE (SHONE AND AULT.)

In the centre of the illustration is seen the 'Ejector' placed underground in a special brickwork chamber. The Afferent and Efferent Sewers are seen at the lower part of the ejector, the efferent sewer opening into the Cast Iron Main which conveys the sewage to the outfall. Running beside the main is seen the Small Pipe bringing the Compressed Air from the Central Compressed Air Station (not shewn), and connected with the Valve at the top of the ejector.

PLATE XI.



LITH: BY ROSS, BROS.

OTHER SYSTEMS OF SEWAGE REMOVAL.

There are three other methods for the disposal of sewage which must be mentioned, *viz.*, The Shone, Liernur and Berlier systems, all named after the inventors, and also a modification of the ordinary methods, termed the Interception system. In the Shone system *propulsion* by means of compressed air is the essential feature, in the other two systems *extraction* by means of a partial vacuum is the means adopted.*

Shone's Hydro-Pneumatic System.—This method is especially suitable in the case of low-lying towns where the sewers cannot be laid with steep enough gradients to carry the sewage to the outfall. There are plenty such towns in the Indian Empire, and one of these, Rangoon, has already adopted this system. Its object is to give, by means of compressed air, an 'artificial head' to the sewage and the effect produced is the same as if the sewage had been pumped up from a lower to a higher level. Careful study of the accompanying plate (XI) will enable the system to be understood in all essential details. The town is first divided into so many blocks or divisions. The sewers converge from each block to a common point where there is placed underground a hollow chamber, the *Ejector*. This has three openings into it—two main openings at the lower part and one small opening at the top. The small opening at the top is kept closed by a valve from which depends a rod carrying a float. The two main openings are simply those of the sewer bringing the sewage to the ejector (afferent sewer) and of the sewer which carries away the sewage (efferent sewer.) The former is closed by a hinged valve opening inwards, the latter by a hinged valve opening outwards. At a certain spot is constructed a complete set of machinery for supplying compressed air at any desired pressure (compressed-air station.) This compressed air is conveyed by a small pipe to the top of each ejector but cannot get into the ejector on account

* *c.f.* Artificial ventilation, p. 24.

of the closure of the valve guarding the upper opening. Suppose now the sewage from a block of houses is gradually flowing into and filling the ejector by gravitation. As it does so, the float is carried upwards and when the fluid in the ejector has reached a certain level the pressure exerted opens the floating valve. The compressed air immediately rushes in at a regulated pressure of so many pounds, the inward-opening flap-valve is closed, the outward-opening flap-valve is opened, and the sewage is forced out and *propelled* to a higher level. It then enters an ordinary gravitating sewer in most cases; or, if the rise has to be more gradual and the sewage carried a long distance, it enters a 'sealed' sewer of cast iron pipes. If the air is compressed 15lbs. to the square inch (1 atmosphere) the sewage will gain an artificial 'head' equivalent to a height of 34 feet. In Rangoon about 7lbs. (or just under 0·5 atmosphere) is usually sufficient.* It is worth noting that in this system the air is compressed at one station, the ejectors acting automatically. This means a saving of labour as compared with pumping stations of which there are ordinarily several.

Liernur and Berlier Systems.—Under the Liernur system the waste water, rain and subsoil water are disposed of by ordinary sewers. The system proper commences in air-closets—as distinguished from water-closets. These are simply iron receptacles of the same shape as a hopper-closet (*v.* pl. vi) with a siphon trap underneath. The excreta, liquid and solid, are passed direct into the closet, but no water is added. It is unnecessary to describe the construction and size of the pipes in detail. They are connected with reservoirs placed at certain spots below the ground, like the Shone ejectors. Instead of a compressed-air station there is in this case machinery for producing an air-vacuum. A vacuum is

* As noted on p. 56, in a town where the Shone system is in use, separate ejectors supplied from the central compressed-air station, but connected with the water mains instead of the sewers, can be laid for giving a 'head' to the water-supply, so that the latter can be distributed, without pumping, to the upper stories of the houses. This has been already done in Rangoon.

produced in the reservoirs and the valve connected with the street sewer is then opened by hand. The sewage rushes in and nearly fills the reservoir, thereupon a little air is admitted and the whole contents of the reservoir drawn away along the outgoing sewer to the central works where the sewage is dried in revolving cylinders and the resulting powder sold as manure. There is a great difference of opinion as to whether the system is an obnoxious one or not; it certainly appears on the face of it as if there were several valid objections to the plan. It will be noted that it does not do away with the necessity for other sewers, for not only rain and subsoil water have to be removed but all waste water except that from closets. As shown before, such waste water is almost quite as impure as when the excreta are added and is quite unfit for direct discharge into a watercourse.

The Berlier system* is a modification of the foregoing and is in use in Paris, the chief distinction being that it works automatically by a floating-valve arrangement, whereas in the Liernur system the valves have to be worked by hand.

Interception System.†—This system has been adopted in this country in the Blacktown sewerage works in Madras. In some cases, as at Berlin, in Germany, the sewers are composed of two parts, as it were (*v.* pl. IX), the lower and smaller part being the channel along which the sewage ordinarily flows in dry weather, and which leads to the ordinary sewer outfall at the sewage farms or other place of disposal. When heavy rain falls this channel is quite insufficient to carry off the stormwater which pours into the sewers in enormous volume. The result is that the entire sewer becomes filled with very much diluted sewage the greater part of which is 'intercepted' and carried off as storm overflow to an outfall into the nearest river or the

* For a good account of this system, *v.* Wallace, *op. cit.*, p. 135, *et seq.*
† The name 'Interception' is sometimes given to systems by which the solid are separated from the liquid excreta. As applied here it has a different significance, *viz.*, the 'interception' and carrying away of storm water to a separate outfall.

sea. In Madras, the arrangement is somewhat different. There the open drains are led into large gullies which have two openings, an upper and lower. Ordinarily, the sewage flows away by the lower opening into the sewers. In storm time the greater part of the mixed rain water and sewage enters the upper opening and is carried by the old drains to the sea on the one hand and to the canal on the other, whilst the remainder, which contains a relatively larger proportion of the sewage, enters the closed sewers through the lower opening in the gully (*v.* pl. IX). When the diluted sewage enters the sea or a tidal water the system is probably a good one and, from the engineering point of view, well suited to a country like this where enormous falls of rain occur suddenly. Where, however, the dilute sewage is conveyed into a river which is a source of water-supply it cannot be considered a very good plan. In addition, it fails to deal with that important thing—the subsoil water. As noted before, sewers should carry sewage only, whilst the rain and subsoil water are removed by drains. Of course, in a low-lying city like Madras the difficulty of doing this is very great. Where an interception system is in force, the best way would probably be to set apart a suitable piece of low-lying waste land near the river and to erect a *band* between this and the river. The dilute sewage, for such it really is, should be made to flow on to and flood this land into which it would gradually sink and be filtered downwards, the considerably purified effluent finding its way into the river. Such a system is at best a modification of the combined system and nothing but urgent pecuniary difficulties could justify its adoption in place of a good separate system. Even in this latter case, however, the original cost and extra taxation would almost certainly be more than repaid by improved general health and freedom from epidemics of filth-diseases.

DISPOSAL OF SEWAGE.

This is one of the most important and most difficult problems of the present day, its importance and difficulty

being chiefly owing to the enormous aggregations of human dwellings which constitute the great cities of the world, *e.g.*, London, Paris, Berlin, Bombay, Calcutta, Madras, etc. In those towns which are properly sewered the amount of sewage to be disposed of daily is almost beyond belief, and in those which are not properly sewered it is absolutely certain that the subsoil of the town daily receives an immense amount of liquid impurity, which forms a hot-bed and nursery for many deadly diseases.

As a result of countless experiments and reports made in connection with this subject a very large number of processes for the disposal of sewage have been invented. These can be classified under several heads as follows :—

(1) The crude sewage is passed directly into the sea or tidal river.—*Direct Disposal.*

(2) The sewage is allowed to 'settle' in large subsidence tanks, the effluent being discharged into a river or the sea.—*Disposal by Subsidence or Mechanical Precipitation.*

(3) The sewage is subjected to mechanical filtration, with or without previous subsidence, the effluent passing on to land or into a river.—*Mechanical Filtration.*

(4) The crude sewage is made to flow over a large area of land whereon suitable plants are grown.—*Irrigation.*

(5) The crude sewage is made to flow over and through small tracts of land previously prepared by deep drainage.—*Intermittent Downward Filtration.*

(6) The sewage is introduced into tanks and some chemical precipitant added, the effluent, after subsidence of precipitate, passing on to land or into a river.—*Chemical Precipitation.*

(7) The Sewage is first treated with a precipitant and then filtered, the effluent passing on to land or into

a river.—*Combined Chemical Precipitation and Filtration.* (International or Ferrozone Process.)

(8) The sewage is exposed to the action of electricity.—*Electrolytic Process.* (Webster).

1. *Direct discharge into Tidal River or Sea.*—Formerly, as before remarked, when sewerage systems were first introduced into Great Britain, the whole of the sewage, waste water from manufactories, etc., were discharged direct into the nearest watercourse or into the sea. The result of this was the creation of a nuisance on a stupendous scale. Rivers which had formerly been the chief ornament of the towns situated on their banks, became nothing more nor less than open sewers, *e.g.*, the River Irwell at Manchester, the Thames at London and countless other rivers. At many seaside places, also, the sewage which was discharged into the sea was carried back by the returning tide and deposited along the beach in front of the town. In 1876 the Rivers Pollution Act was passed making it illegal to discharge crude sewage into streams, which term included rivers, canals, lakes and most watercourses; also the sea and tidal waters, except under certain restrictions and conditions. Unfortunately, owing to powerful opposing interests, the Act has been to a large degree inoperative, but there is reason to believe that it will be administered with greater strictness in the future.

For a long time it has been a disputed matter to what extent sewage, if discharged direct, or after partial treatment, into running water, becomes purified. Many interesting experiments have been made and reports submitted but the matter is by no means completely settled yet.* It is certain that river water which has been polluted may, in process of time, regain its purity so far as any available tests can show. But, to bring about such purifi-

* Even now, the authorities in the town of Aberdeen in the north of Scotland are undecided, on account of this difference of opinion, as to whether they can safely take water for the supply of that town from the river Dee, this same river receiving sewage from towns situated higher up in its course.

cation many conditions are necessary, *e.g.*, a course of many miles of the river free from any fresh or additional contamination, a rapid current, suitable temperature, etc., and it is impossible, in any river, to ensure that these conditions will always be fulfilled. As a matter of fact a river passing through an inhabited country is almost certain to be fouled at frequent intervals. In England "rivers which are once polluted with sewage so continually receive fresh accessions of sewage from towns situated lower down on their banks that the processes of self-purification are brought to a standstill, and the contamination of the water gradually but constantly increases from the source to the mouth of the river."* In this country, of course, the chief rivers are larger and longer, and though large towns are not so closely placed along their banks and they do not receive the same quantity of waste water from manufactories, still they are continually being polluted by filth of all sorts from towns and villages. In fact the smaller rivers are so foul already that in many cases they are in much the same condition as if large sewer outfalls opened into them. It will be seen then that many rivers are ordinarily so impure that any additional sewage purposely discharged into them would render them hopelessly foul. Finally, it must be remembered that many rivers, except the largest, dry up almost completely during several months of the year and could not therefore be used to carry off sewage from any town.†

The actual process of purification which sewage undergoes in running water is brought about chiefly through oxidation of the impurities by the oxygen dissolved in the water.‡ There is little doubt that certain kinds of bacteria

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* S. and M., *op. cit.*, p. 851.

† In Madras may be seen the horrible sight of sewers discharging their liquid filth into the more or less dried-up salt backwater named the Cooum. The sewers open many feet from the nearest water, and, as the water from the sewage which trickles out of the drains evaporates quickly, there is left a daily-increasing foreshore of black and most offensive slime. It is almost beyond comprehension that such a state of matters has been permitted to arise and continue in the capital town of a Presidency.

‡ *v.* p. 66.

and other micro-organisms play an important part in bringing about this oxidation. Additional oxygen is partly derived from solution of fresh atmospheric oxygen as the water runs over shallows and partly from the vital processes of the numerous water plants which grow in running water. The sewage matters also serve as food for certain fishes and for the countless low forms of animal life, *infusoria entomostraca*, etc., which flourish in impure water and which, apparently, may play a very important part in disseminating disease.* Subsequently, if fresh additions of sewage are made to the already impure water, the total available oxygen is quite insufficient, the fishes and plants die, and the number of putrefactive micro-organisms becomes greatly increased. Active fermentative processes are then set up and the river becomes simply an open sewer from which most offensive odours are given off. It is extremely difficult to trace outbreaks of particular diseases directly to such a state of things, unless such foul water is used for drinking purposes, but there is abundant evidence that it produces a low state of vitality in those who are forced to reside in the neighbourhood, so that they are only too liable to fall victims to any prevalent disease, *e.g.*, cholera.

With regard to the discharge of sewage into tidal waters there are many interesting points which cannot be dealt with here. The proper way, as before mentioned, is to store up the sewage in suitable tanks at the outfall and discharge it just as the tide begins to ebb. When salt or brackish water, however, comes in contact with fresh sewage, active chemical changes take place and the organic matters in the sewage are largely precipitated. If this goes on day by day a very considerable amount of offensive matter is deposited and in time may form a bank of sufficient size to interfere with navigation. The sewage may be carried back a considerable distance by the flowing

* *v.* p. 85, *et post*. Parasites of Man.

tide, or by variable currents, and cause a grave nuisance.* A peculiar and disagreeable smell, due to the formation of a chlorinated compound, is noticeable when crude sewage and salt water meet.

If then crude sewage is to be discharged into a tidal water or into the sea direct, many precautions must be taken and careful study made of the tides, currents, relative position of the town, etc., etc. It is very doubtful if it should ever be allowed, more especially in this country where it is so urgently needed for irrigation and manurial purposes. Under no circumstances should crude sewage be discharged into a river above the tidal reach.

2. *Mechanical Subsidence in tanks* and 3. *Mechanical Filtration, with or without previous subsidence.*

These two processes belong to the period when attempts were first made to purify sewage ere discharging it into a river. In the first case it is to be noted that large and costly 'settling tanks' are necessary and that the suspended matters are only very slowly deposited. In the second case the filters, made of gravel, charcoal, etc., soon become blocked and are costly to renew. The effluent in both cases is still highly impure and quite unfit to discharge into a river. Both processes are practically obsolete and need not be further described. Partial subsidence or straining, however, are still employed in many cases, ere allowing the sewage to flow on to land.†

4. *Irrigation.*—There are two methods of irrigation in use, *viz.*, *Broad* or *Surface* Irrigation and *Subsoil* Irrigation. The first method is by far the commonest and is undoubtedly of great importance in connection with sewage disposal in this country. It will be considered first and in considerable detail. Careful distinction must be drawn between this process and that known as Intermittent Filtration.‡ It is defined as the *distribution of sewage over a*

* As at London, or Loch Fyne in the W. Coast of Scotland.
† *v. post.* Irrigation and Intermittent Filtration.
‡ *q. v.* p. 183.

large surface of ordinary agricultural ground, having in view a maximum growth of vegetation (consistently with due purification) for the amount of sewage applied. That is to say, the sewage is allowed to flow over the ground, into which it sinks and is filtered, its products being oxidised and utilised as food for the crops grown on the land, whilst the filtrate or effluent passes into drains laid at a suitable depth and is carried along an outfall for discharge into a river or into the sea. The first essential in starting a sewage irrigation farm is a piece of ground *with a gentle slope towarde the outfall,* if possible, situated at a *convenient distance from habitations, moderate in price* and with a *soil of the proper kind.* The best kind of soils are light sandy soils with, if possible, a subsoil of gravel. The 'poorer' the soil the better, and pure sand is much preferable to a rich soil which is naturally damp and retentive of moisture.* As regards the amount of land which is necessary that depends primarily on the population of the place and secondarily on the kind of soil. In England it is generally stated that 1 acre should be allowed to every 100 persons; no rule available for all circumstances is possible. The number per acre will vary from 50 to 200 according to the nature of the soil and the average amount of sewage per head. In India, owing to the general absence of water-closets and to the rapid evaporation, the amount of land required for a given number will probably be less than in a European town.

The sewage is conducted by the main sewer to the highest spot on the farm.† From here it may be allowed to pass at once on to the land or may be roughly strained so as to remove any large solid matters.‡ The main

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* *v.* pp. 114-5. Almost any soil can be rendered more or less suitable by a little expenditure; careful under-draining is most essential save in the case of very sandy and porous soil immediately adjoining the sea.

† It is preferable to choose a piece of ground with a good natural slope so that the sewage can gravitate over the soil and be carried away by the under-drains. If the land is low-lying, pumping must be resorted to and this, being expensive, takes away a large amount of any profit otherwise accruing.

‡ In some cases irrigation is secondary to mechanical or chemical pre-

carriers are simply open channels of brick and cement or concrete, and are easily flushed and kept clean. The land itself is usually laid out in broad ridges from 30 to 50 feet across which slope away from the main carrier on either side. The ridges are parallel to each other and between each pair is a furrow or shallow channel in the earth. Down the centre or crest of each ridge there is also a grip or shallow channel. The sewage is applied intermittently* to various portions of the land; if applied continuously, the ground becomes water-logged, oxidation processes are at a standstill, and the land is said to be 'sewage-sick.' When any piece is to have sewage applied to it, a sluice is lowered in the main-carrier, or a piece of wood called a 'stop' is placed across it, thus damming back the sewage. The main-carrier then overflows, the sewage running down the grip in the crest of the ridge. This is blocked at intervals with earth and opened again† so that the sewage is made to flow by degrees all over that particular ridge. On the ridge is grown some suitable crop. Any sewage that does not sink into the soil on the ridge, runs into the furrow between the ridges. Ultimately, if the farm is properly managed, the whole sewage is absorbed by the soil and disposed of as before mentioned.‡

A great deal depends upon whether the town which

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cipitation, in other cases it is combined with intermittent filtration as will be explained afterwards.

* The number of hours or days during which sewage is allowed to flow on to a particular piece of land varies according to the absorptive power of the soil, the crop which is being grown, the weather and climate. In this country, probably, owing to the very rapid evaporation of moisture exposed to the direct rays of the sun, the period of flow may be rather longer than in colder countries.

† As is done by ryots in irrigating rice fields. Notice also that here the channel scooped out of the earth fulfils its proper function of *allowing* the sewage to sink into the subsoil: *cf.* the use of similar channels in the neighbourhood of houses in this country, where their proper function is to carry away the sewage and to *prevent* its sinking into the subsoil. *v.* p. 148, and Plate VII.

‡ The above is generally known as the 'ridge and furrow' system. There are many other plans adopted according to varying circumstances, but the principle is the same. The system in use in Madras is slightly different, the most important being that there is no under-drainage. For full description of the same, *vide* appendix, Madras Sewage Farms.

supplies the sewage is sewered on the separate or combined systems. In the former case, as explained before,* the amount of sewage to be dealt with is very much less than in the latter case which includes, in addition to the sewage proper, the greater part of the rainfall and all the subsoil water. Again, at certain times, *e.g.*, the Indian rains, the amount of sewage to be disposed of under the combined system would be enormous and would interfere very seriously with the working of the farm. Either the soil would become completely water-logged and the effluent only be half purified, or else a large part of the sewage would have to be disposed of elsewhere.† As a matter of fact there are several ways of dealing with an excess of sewage, which farms connected with a combined system have been forced to adopt. When the soil is almost pure sand and there is abundance of cheap land, it would be sufficient merely to turn the excess of sewage on to fresh waste land and let it gradually sink in, provided that there was no possibility of its contaminating any water-supply. Another plan is to choose a piece of land adjoining the irrigation fields, where the soil is as porous as possible, and to prepare it for intermittent filtration as described under the next heading. The proper plan, however, is *only to bring real sewage to the land*, as much rain water as possible and all subsoil water being excluded.‡ Of what use then are these sewage-farms from other points of view? As a rule they are merely utilised for raising one or two crops of grass in this country but in the near future there is little

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* *v.* Table comparing separate and combined systems, p. 160.

† It is to be noted here that in India, typically in Madras, the sewage farms are on a relatively small scale. In Madras there are many farms each dealing with only a small portion of the town. Owing to the enormous falls of rain in this country, in a short time, the combined system of sewerage is quite unsuitable. A modification of it, known as the Interception system, whereby the storm waters are carried direct to the nearest outfall in rainy weather, is in use in Blacktown, *v.* p. 171. I believe it to be a most dangerous error to say that sewage diluted with rainwater is harmless and can be discharged into a possible source of drinking water; especially in India where the sewage always contains excremental impurities.

‡ In fact, the oft-quoted maxim 'The rain to the river, the sewage to the soil,' applies correctly.

doubt their uses will be considerably increased. They afford excellent grazing for cattle of various sorts and it is very doubtful whether there is any chance of disease being communicated to the animals, and thence to man, from such a practice; although at one time the danger was regarded as considerable. In Madras the chief crop raised is *hariali grass* for which there is considerable demand. It grows most luxuriantly and forms a marked contrast to the stunted and earthy bundles brought in from the country by the grass-cutters. *Guinea grass* and *lucerne* grow well,* but there is not such a demand for them. In England many different sorts of plants are grown and find a ready sale. At Craigentinny, near Edinburgh, irrigation has been carried on for many years, the formerly barren ground yielding many crops of well-grown rye-grass every year. With care, wheat, oats and other cereals can be raised and, in this country, rice. Tap root vegetables, such as turnips, beet-root, rabi, etc., do well, likewise potatoes, if not over-sewaged, and many other crops. If there is any surplus of sewage, it can often be sold to cultivators with land in the immediate neighbourhood, care being taken that proper restrictions are put in force with reference to the working of the sewage-cultivated land.

Subsoil Irrigation is a process allied to the foregoing and is specially suitable for isolated institutions like jails, barracks, etc., where the drains do not connect with any sewerage system and the sewage has to be disposed of at a short distance from the buildings. The usual way of getting rid of the sewage in such cases is by the use of cesspools or by discharging the sewage into a neighbouring stream which probably receives sewage from numerous other farms or houses and is simply an open sewer. Subsoil irrigation, if properly carried out, is much preferable in every way. It can be applied also to villages but, in this

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* They are growing well at the present time at Government House, Ootacamund, the crops being irrigated with sullage water from the dwelling lines and stables.

country, broad irrigation is likely to be more generally adopted.

A piece of ground is chosen, as in the former case, situated at a lower level than the buildings and with a gentle slope. The sewage is conveyed to the ground by the ordinary water-tight pipe sewer from the house or houses and flows into under-ground porous drain pipes,* about two inches in diameter, which are placed at a depth of half to one foot under the soil, their joints being open. These pipes are laid in rows about six feet apart and ramify through the selected piece of ground. Their ends are laid upon cradles made of half pipes and are covered above in a similar manner so as to allow the sewage to escape, whilst preventing earth falling into them (*v.* pl. vii.) In a loose, porous soil this is all that is required; when it is denser and more retentive, a catchwater drain should be laid at the lowest point to convey the effluent to the nearest stream. If the amount of sewage is small, it may be necessary to use an automatic siphon flush tank (*v.* pl. x) which allows the fluid to accumulate for a certain time and then discharges the total amount with considerable force.†

The process of purification is much the same as in surface irrigation, the sewage, as it passes out of the open pipe joints, being exposed to the action of the roots of growing plants—grasses, vegetables, etc., and to oxidation processes in the soil.

It is, of course, of extreme importance that the effluent in sewage farms, when there is any, should be of sufficient purity to ensure its being safely discharged into water, so that there may be no risk of its contaminating a water-supply. Now, its purity depends upon several things which

* Ordinary agricultural drain-pipes will do. If excreta or other solid matters are added to the sewage, it is customary to strain the solids off, first and to dispose of them by spreading on land and digging them in. *v.* p. 152.

† This practice is much the same as that alluded to on p. 152, only here the sewage itself fills the tank and scours the sewer, whilst in the case of large sewers the scouring is done by clean water from the water-main.

may be included under the management of the sewage farm. If the ground is properly prepared and of suitable nature, the under-draining carefully done and the sewage not too continuously applied to any one part, then the effluent is wonderfully pure. The organic impurities, estimated as so much nitrogen, are very much reduced in amount. The suspended organic impurities should be completely removed, whilst the nitrogen in the dissolved impurities is almost entirely in the form of harmless nitrates and nitrites.* In other words, by bringing the sewage to the soil the latter is supplied with a most valuable and easily-assimilable† manure, whilst the former, which is otherwise a continual menace to health and a standing nuisance, is completely got rid of.

5. *Intermittent Downward Filtration.*—By the process to which the above name is given is meant the *concentration of sewage, at short intervals, on an area of specially chosen porous ground, as small as will absorb and cleanse it; not excluding vegetation, but making the produce of secondary importance.* In other words the soil is here the principle purifying agent, the action of the roots of growing plants being an additional and non-essential, though usual, part of the process. A suitable piece of ground is chosen, as in surface irrigation, only in this case the amount required is much less. It is divided into 'lots' of equal size. As regards the proper sort of soil, what has been

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* "All the constituents of sewage are greatly reduced by irrigation, with the exception of chlorine, which is very slightly reduced, or even sometimes apparently increased, owing to the concentration produced by evaporation: but the constituents which are most effectually removed from sewage are especially the putrescible organic matters—those, namely, which it is essential to remove both from an agricultural and sanitary standpoint. Nitrates and nitrites do not exist in sewage, but are usually found in the effluent water to some extent, and are evidence of the oxidation processes to which the sewage has been exposed in the soil." S. and M., p. 883.

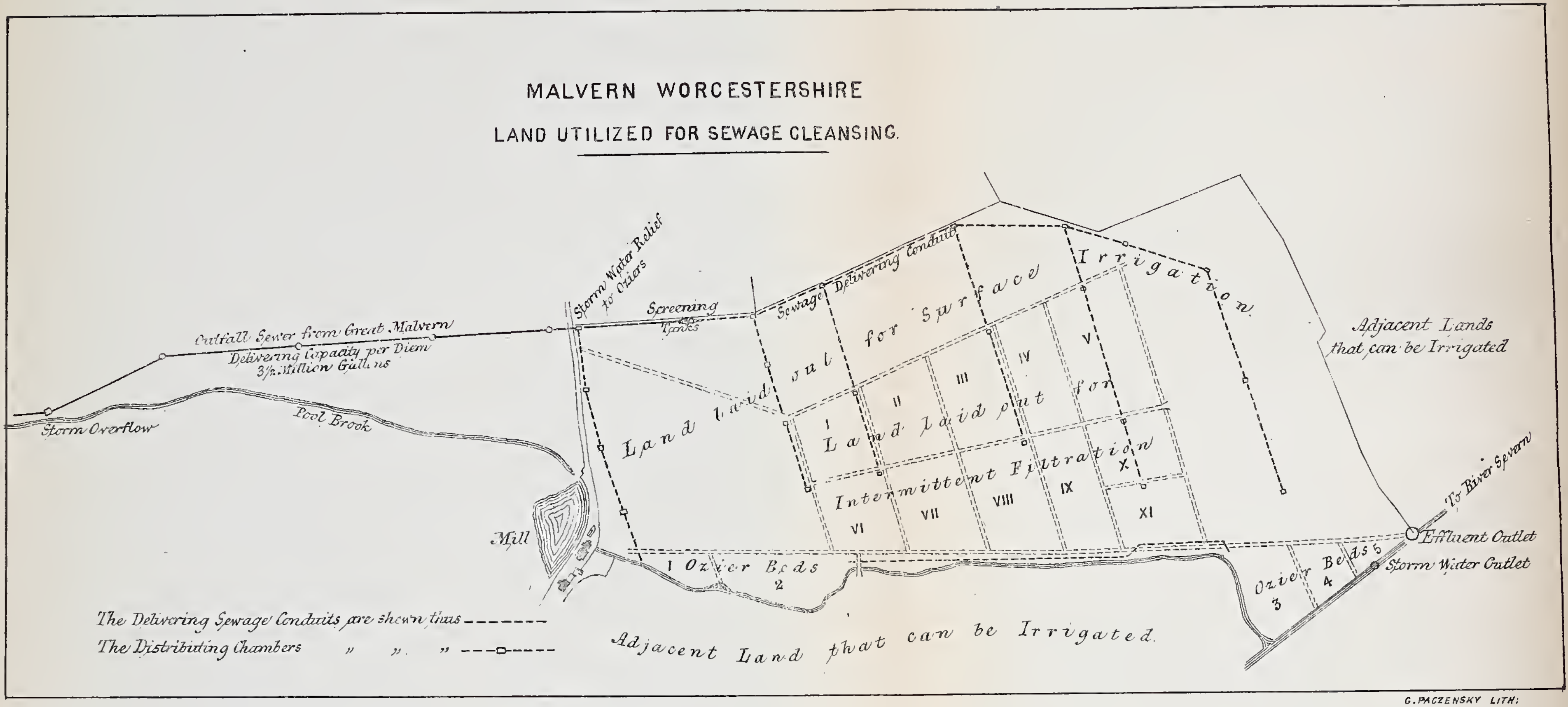
† It should be noted that in the case of liquid sewage the nourishment supplied is mostly brought to the roots of growing plants already dissolved and is quickly assimilated. Where excreta and general dry refuse are dug into the soil and buried, the crops have to be sown afterwards, and it takes some considerable time for the organic matter to be brought into an easily assimilable form for plant nourishment.

said of surface irrigation applies equally here. The best soil is a sandy loam with a small proportion of gritty gravel to quicken percolation. The soils most unsuitable are very dense clays, bog peat and very coarse gravels. Any soil which cracks during dry weather, *e.g.*, black cotton soil, is thoroughly unsuitable, as the sewage simply flows down the cracks and reaches the effluent outfall quite unpurified.*

The sewage is brought to the highest part of the ground and is roughly screened of its larger solid matters. It is then ready for distribution which is so arranged that it can be made to gravitate slowly over the various plots of land in order. For six hours each plot receives the sewage and for eighteen hours the flow is intermitted. By this means the soil has time to recover itself, so to speak; in other words, it becomes re-aërated and is able to re-commence the purification of fresh supplies of sewage. First of all, the ground is very carefully levelled to ensure even distribution of the sewage and is then dug into small ridges and furrows. On the ridges vegetables or other crops are planted and the sewage flows along the furrows. At the commencement, it mostly sinks into the furrows, but after a time, when the furrows have become lined with a deposit of the suspended matters known as 'sludge,' the sewage does not sink readily into the furrows, which resist the infiltration, but is "driven into the ridges on each side." In this way the liquid sewage is brought

* Note also that the capacity of soils to absorb water is no criterion whatever of their cleansing capability, whilst their *retentive* powers exercise great influence on the rate of percolation and the quality of the effluent. A coarse gravelly soil thoroughly drained, for instance, will absorb and discharge liquid almost as quickly as it reaches the surface and will give out an effluent but imperfectly purified, whereas a loamy soil, having a sufficient proportion of sand to render it free and to fill it with close interstitial spaces for aëration, will discharge a satisfactory quantity of purified water by under-drains and maintain a very superior effluent. Closely related to the absorptive and retentive powers of soils is their evaporating property, the effect of which at certain times of the year is so great that in cases where there is no subsoil water to dilute the effluent, the quantity discharged has been less than half the quantity of the sewage distributed over the surface. *v.* Sewage Disposal, Bailey-Denton, 2nd ed., p. 49, *et seq.*

Plate XII.



G. PACZENSKY LITH:

To face p. 184.

PLATE XII.

PLAN OF SEWAGE FARM AT MALVERN, IN ENGLAND.

(After Bailey-Denton).—The Plan shows the Land Laid Out for the Cleansing of Sewage by Intermittent Downward Filtration, and by Surface Irrigation, with Storm Water Reliefs to Ozier Beds; the Effluent passing into the River.

into contact with the *roots* of the vegetables only and does not contaminate their stalks and leaves. Afterwards, when the furrows are filled with sludge, the latter is allowed to dry partially and is then lifted out and dug into the ridges.

The soil is under-drained precisely as in surface irrigation, the drains being very carefully laid at a depth of about four feet from the surface. If the process is properly carried out, the effluent will be very pure, as in surface irrigation, and can safely be discharged into a watercourse.

The preparation of the land for intermittent downward filtration is more expensive than for surface irrigation, but much less land is required. Some authorities advise the previous clarification of the sewage by chemical treatment (precipitation processes); (*a*) because the slimy matters in crude sewage tend to block up the pores of the soil by forming a thin pellicle on its surface and (*b*) because the sewage does not putrefy to such an extent after chemical treatment and therefore undergoes nitrification more easily. In this country it is very unlikely, save possibly in the largest towns, that any such chemical treatment will be adopted. If precipitation is resorted to in the first instance, it means that an enormous amount of 'sludge' will be accumulated, the disposal of which will be a matter of extreme difficulty. Careful arrangement of the ground, so that the crude sewage *gravitates slowly* along furrows, the latter being cleared at intervals and the deposit dug into the ridges, appears much simpler and more suitable in every way for adoption by Indian municipalities.

Intermittent downward filtration is very rarely, if ever, adopted to the exclusion of surface irrigation. This latter is nearly always combined with it so that part of the farm is laid out for intermittent filtration, the remainder, and larger portion, for broad irrigation. In most cases there is also a special piece of ground, laid out in ridges

and furrows and planted with osiers,* set apart for storm overflows in time of very heavy rain. It is not underdrained and merely serves to check the rush of storm water, which is prevented from flowing into the ordinary filtration area until most of the suspended matters have subsided in the furrows and the liquid has undergone a certain amount of clarification by flowing over the ridges and amongst the osier roots.

6. *Chemical precipitation.*—This method of purifying sewage is essentially the same in principle as that sometimes adopted for removing the suspended impurities in drinking water.† It consists in the addition to the sewage of one or more substances that form a precipitate which carries down in its meshes the greater part of the suspended matters and sometimes a small portion of the matters in solution. An enormous number of processes have been patented from time to time, but of these only very few need be noticed here and very briefly. *Lime,* as milk of lime,‡ or simply as lime water, has been largely used for a long time and is the chief or only precipitant in a number of cases. *Aluminous* substances, in one form or another, are also in great favour. Impure sulphate of aluminium, the refuse of alum works, aluminous earth with sulphuric acid added to it, alum and powdered clay mixed, have all been tried. A favourite mixture is milk of lime and sulphate of alumina.

Lime, when added to sewage, exerts the same action as when added to water in the process of 'Clarking,'§ the insoluble carbonate of calcium carrying down the greater part of the suspended matters in the sewage. If too much lime is added, the effluent is rendered distinctly alkaline and, although the precipitation is very rapid and the

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* Osiers are plants with thin flexible stems which are used in basket-making, etc., as cane and bamboo are used in this country. They are not an essential feature of such storm overflow reserves (*v. ante*, p. 172), but help to retard the flow of water by their long twisting roots much as mangrove roots do in a swamp. No doubt some other plant, such as oleander (?), could be utilised in the same way in this country.

† *v.* p. 87. ‡ *i.e.*, lime slaked and added to water. § *v.* p. 73.

effluent clear, it has been found that the excess of lime causes solution of some of the previously suspended matters. Thus the effluent is really made more impure and, being strongly alkaline, undergoes secondary fermentation or decomposition* more readily. Now, one great object of the chemical treatment of sewage is to prevent this secondary decomposition taking place, in order that the effluent, when discharged into a river or other watercourse, may not give rise to nuisance. The lime process, then, cannot be considered sufficient of itself.

Sulphate of aluminium has likewise the same action on sewage as when added to drinking water†, a bulky, flocculent precipitate of aluminium hydrate being formed, whilst the sulphuric acid combines with the calcium in the sewage to form sulphate of calcium. The effect on the sewage is much the same as in the lime process, save that the impure aluminium sulphate being slightly acid the effluent is neutral or even acid. This tends to prevent secondary decomposition taking place, but an acid effluent is unsuitable for irrigation of growing plants. It has, therefore, become customary to use these two substances, *viz.*, lime and sulphate of aluminium, together, the special object being to produce an effluent and precipitate which are neither acid nor alkaline, or, in other words, as nearly as possible neutral.‡

Amongst other substances which have been used as pre-

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* By secondary decomposition is meant the fermentation which takes place in the effluent—which contains nearly all the original dissolved impurities—after it is discharged into a stream or otherwise disposed of.

† *v.* p. 73.

‡ To sewage of average strength the amount required of each substance is about 5 grains per gallon of sewage. The Corporation (Municipality) of the city of Glasgow have recently determined to adopt this process for part of the sewage of that town. The new works will deal with the drainage of an area of 26,035 acres, representing 10,000,000 gallons of sewage *per diem*, from a population of 265,000. The sewage will be treated with sulphate of aluminium and milk of lime: after precipitation it will be aërated, to promote oxidation, and then filtered, the clear effluent being passed into the river Clyde (not used as a water supply for domestic purposes). The sludge will be compressed by air into cakes and, in conjunction with other refuse, may be available for manurial purposes. *v.* Brit. Med. Jour., 18th March, 1893, p. 598.

cipitants are charcoal, bone ash, black ash, chlorides of sodium and calcium, sulphate of zinc, magnesian and iron salts, tar, creosote and many other things, most of the processes being known by the name of the inventor. It is unnecessary to describe any of them in detail here.

In dealing with sewage by such 'chemical' processes, there are several things to be kept in view. (1) The process must be made to pay the whole or part of the cost if possible. (2) Care must be taken to prevent the possibility of a nuisance being caused. (3) The effluent must be rendered so pure, if possible, as not to interfere with the use of the river as a drinking water supply, or at all events so as not to interfere with the animal and plant life in the river. For consideration of these points, it is best to divide the subject into two parts, discussing the precipitate first and then the filtrate.

The disposal and utilisation of the precipitate or *sludge,* as it is called, is a matter that is by no means satisfactorily settled. When the sewage is brought fresh to the works, the larger solid matters are removed by straining. Afterwards the chemicals are added to the sewage as it flows along, so that the two are well mixed ere arrival at the precipitating tanks. In order to permit of periodical emptying and cleansing, a double set of two or three tanks in line is usually provided. The sewage is allowed to flow slowly but continuously through one set of tanks for several days, and then, after all the effluent has flowed away, the sludge is allowed to settle. Thereafter, being more or less in a fluid condition, it is forced up in pipes to the filter presses, where it is compressed by air into cakes, the excess of liquid, which is still very impure, flowing away for treatment again. It still contains over 50 *per cent.* of moisture and it takes about 850 tons of sewage to produce one ton of such sludge. Consisting, as it does, chiefly of water and mineral matter its manurial value is very small, hence its market value is almost *nil* and in many cases farmers actually demand payment to remove it. In one

process, known as General Scott's or the 'sewage-cement' process, lime and clay were used as precipitants, the resulting sludge being dried, burnt in kilns, ground into fine powder and sold as cement.*

As regards the filtrate or *Effluent*, it is of extreme importance to note that, though the major part of the suspended matters are got rid of, the dissolved organic matters are untouched. Now, these dissolved impurities are just those which are most valuable from the agricultural and most hurtful from the hygienic point of view. Wherein then lies the advantage of the chemical treatment of sewage? In the case of a city like Glasgow where the chief object is to prevent the creation of a nuisance in the Clyde and neighbourhood, where the river is tidal above the point of discharge of the effluent and is not used as a source of drinking water, it may be sufficient to remove the suspended matters and to take means to prevent the effluent undergoing secondary decomposition. But in the case of inland cities the conditions are different and chemical precipitation processes are of themselves quite incapable of dealing satisfactorily with large volumes of sewage. The only reliable method, and one which is being adopted more and more, is to treat the sewage first of all by chemical precipitation, *if necessary*, and then to pass the effluent on to prepared land either for surface irrigation or intermittent downward filtration.

7. *International* (*Ferrozone*) *Process.*—This is a somewhat novel process which has been tried near London with a considerable degree of success. The sewage is first treated with a precipitant called ferrozone,† the whole of the suspended and some of the dissolved matters being thrown down. The effluent is then passed through two

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* *cf.* treatment of material produced by burning dry refuse in incinerator, *v.* p. 145.

† Called 'magnetic ferrous carbon' and consisting largely of protosulphate of iron.

filters by intermittent downward filtration, the filters being composed, from above downwards, as follows :—

Nine inches of sand.
Ten inches of mixed sand and polarite.*
Six inches of sand.
Four inches of gravel the size of peas.
Coarse gravel, which is intersected with catch-water drains laid on the floor of the filter.

The filtration is conducted slowly, the filter beds being used intermittently to allow of fresh aëration. The polarite can be used for a long time, but the sand must be changed at fairly short intervals. The resulting effluent is wonderfully pure and contains nitrites and nitrates, showing that a considerable amount of oxidation takes place. It is claimed that one acre of such a filter bed will purify from one to two million gallons of clarified sewage daily. From a hygienic view the process seems to be a success, but it is a costly one. It appears suited for well-to-do towns situated on inland rivers, where land suitable for irrigation or downward filtration is not available.

8. *Electrolytic Process.*—The application of electricity to the treatment of sewage is the idea of Mr. Webster, F.C.S., who remarks—"The oxidation of organic matter can only be obtained by one mode of chemical action, whether it be by filtration accompanied by the action of micro-organisms, the addition of chemicals or mechanical force represented by the electric current." The sewage is made to pass through two 'electrolytic shoots' or brickwork channels divided into cells containing iron plates. Every alternate plate is connected respectively with the positive and negative poles of the generator.† During the passage of the sewage through the shoot, a flocculent precipitate of hydrated ferrous oxide (?), produced by the action of the electric current on the iron electrodes, is formed. The

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* Called 'magnetic spongy carbon,' and consisting largely of magnetic oxide and carbide of iron.

† A dynamo driven by a steam engine.

resulting effluent is very considerably purified and, apparently, all living organisms destroyed, so that it does not readily undergo secondary fermentation. Very little extraneous matter is added to the sewage and this means that the amount of sludge is relatively small. The process, however, is a costly one both on account of initial outlay for plant and the waste of power, and the resulting sludge has no great value. Its use will probably be confined to certain towns where the amount of manufacturing refuse is very great and not easily amenable to other treatment.*

HEALTH IN RELATION TO REMOVAL OF REFUSE MATTER.

This, of course, is the most important part of the subject now under consideration. It is quite right that pains should be taken to ensure that no accumulations of filth shall be allowed to pollute the air or offend the eye, and it is also quite right that the removal of all refuse be done at a reasonable cost, if possible, and that it be disposed of at a profit likewise, if possible. But *the* point for consideration of sanitarians is—*How best to remove and dispose of all refuse so as to minimise the risk of disease being caused by it, directly or indirectly?* Before taking up this point, however, it must be seen what is the experience of India and other countries in this relation.

The most important enquiry in England in this direction was that carried out by Dr. Buchanan, but, of necessity, it did not deal merely with the introduction of sewerage systems, but with sanitary works as a whole.† It is extremely difficult in most cases to assign accurately to each sanitary factor its part in lessening disease, but it can sometimes be done: the result is, in many cases, sufficiently startling. Buchanan chose twenty-five towns of varying size where sanitary improvements had been instituted for some time, and the general result was that of

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* For an account of the process in considerable detail, *v.* paper by Dr. MacLintock. Brit. Med. Jour., 30th August 1890.

† Including improvements in house, subsoil and surface drainage, improvements in water supply, in removal of town refuse generally, and in the ventilation, etc., of lodging houses.

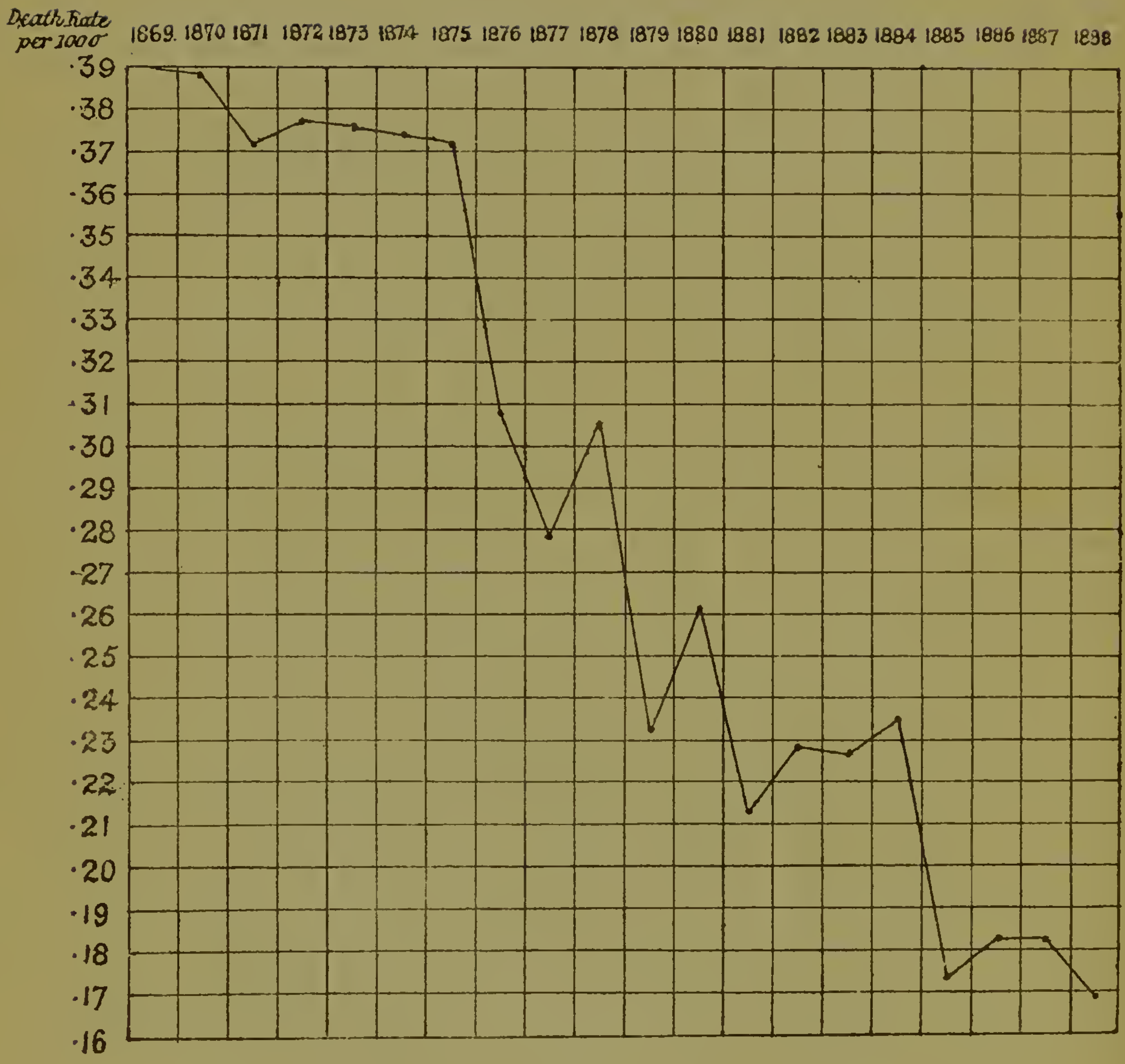
these towns twenty showed a reduced death-rate since the completion of the sanitary reforms. This reduction was especially due to the diminished mortality from enteric fever and cholera, as also, no doubt, to a generally-improved condition of health leading to a greater resistance to attacks of disease. For further details the original report may be consulted.* In the town of Munich, in Germany, since the introduction of a sewerage system in place of the former porous cesspools, the average annual number of deaths from enteric fever has fallen from 208 to 40. The accompanying table (pl. xiii) shows clearly the wonderful diminution in enteric fever mortality which has taken place in England and Wales from the year 1869 onwards, the decrease being specially marked in the years 1876-77.†

Coming now to this country, it may at once be stated that the available information and experience are far from what they should be. The cause of such a state of matters need not be discussed here, it will be remedied in time to come and with results that will appeal to the most sceptical. Of one thing there is absolutely no doubt, and that is *to the present ignorance and apathy concerning the significance and means of effective removal and disposal of the refuse of towns and villages, and especially the excreta, is due to a very large proportion of the diseases which decimate the inhabitants.* "It has long been," says Sir John Simon, "among the most fixed of the certainties which have relation to civilised life, that wherever human population resides, the population cannot possibly be healthy, cannot possibly escape recurrent pestilential diseases, unless the inhabited area be made subject to such skilled arrangements as shall keep it habitually free from the excrements of the population." It cannot be denied that there is, at

* *v.* Ninth Report of the Medical Officer to the Privy Council. *v.* also extracts from the same in Public Health Reports, Sir John Simon, Vol. ii, p. 262, *et seq.*

† The Public Health Act was passed in 1875, leading to the appointment of District Medical Officers of Health and consequent great improvement in sanitary matters, especially those relating to refuse removal and pure water supply.

Plate XIII



Death Rate per 1000
1869. 1870 1871 1872 1873 1874 1875 1876 1877 1878 1879 1880 1881 1882 1883 1884 1885 1886 1887 1888
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PLATE XIII.

TO ILLUSTRATE STEADY DECLINE IN TYPHOID FEVER MORTALITY, IN ENGLAND, FROM THE YEARS 1869 TO 1888 INCLUSIVE.

(STEVENSON AND MURPHY.)

present, no single town in India habitually free from the excrements of the population. Most praiseworthy efforts to bring about such a state of things have been made by sanitary authorities, but as yet the lions of ignorance and sloth have barred the way. Individual effort and example are wanted and until the people as a whole are shown that carelessness with regard to the disposal of refuse of all sorts, and of excreta in particular, is a *crime*, it is hopeless to expect much improvement in the present condition of matters throughout the Empire.

In the larger towns efforts have been and are being made to deal effectively with the subject, but they are, as a rule, partial and incomplete. "Rangoon is now the only city in the Indian Empire which can boast of a scientific system of drainage which fulfils all the requirements of sanitarians." Previous to 1873 the land was honeycombed with cesspools and the drinking water correspondingly polluted. Thereafter the cesspools were closed by order and the night soil collected by carts and thrown into the river. This horrible system obtained till 1890 when the Shone system was adopted at a cost of more than twenty lakhs of rupees. With thorough conservancy of dry refuse, a good water supply and efficient subsoil drainage, supplementing the effect of such a system of sewage removal there is little doubt that this great and rapidly-increasing city will take the lead in healthiness from her more conservative and poverty-stricken Indian neighbours. Bombay is likewise making a laudable attempt to deal with her enormous mass of liquid and solid refuse. Up to 1891 about 56 miles of sewers had been laid. "The main principle on which the sewerage works have been designed is to secure segregation of storm-water from the sewage, a necessity consequent upon the concentration of the annual rainfall within a short period of the year, and on the inability to construct channels to do the dual duty of sewers and drains under the variable conditions of flow during the dry and wet seasons. Before the new works were commenced, the city was drained by flat-bottomed

masonry drains, many of vast dimensions, which received both storm-water and sewage, and which during fair weather became merely elongated cesspools. Under the present project, the main sewers have been constructed on the most approved and modern principles of sanitation. The sewerage works when completed will cost probably not less than £1,000,000," or more than 130 lakhs of rupees. Calcutta and Madras have also made attempts to provide themselves with good sewerage systems but, for various reasons, with not conspicuous success. In all these cities and in many others the question of effective disposal of dry refuse by fire is also being considered, so that, given rapid removal and disposal of both dry and liquid refuse, one great evil will have been abolished.

As said before it is too soon to attempt to reckon the good which will result from such reforms, added to which is the very imperfect registration both as to the number and causes of deaths in these towns. If these remarks are true for the chief towns in India much more are they true for the smaller towns and numberless villages. At present sanitary reformers can but continue quietly and persistently the great work of cleansing these Augean stables, confidently leaving the justification and approval of their doings in the hands of their successors.

WHAT SYSTEMS OF REMOVAL AND DISPOSAL OF REFUSE ARE BEST FOR INDIA?

Having thus briefly described the various methods for removal and disposal of waste matter, including excreta, and considered very shortly the influence exercised on the health of towns by such rapid and systematic removal, it is necessary to examine and compare together these methods with reference to their relative merits for adoption in the towns and villages of this Empire.

Firstly, then, let these two axioms again be carefully noted :—In adopting any conservancy system whatever, provision has to be made for the removal of both wet and

dry refuse, and,—Whether the excreta are added intentionally to the waste water (sullage) or not, the latter is highly impure and, unless quickly and suitably disposed of, becomes a nuisance and a danger to health. There are thus three things to be considered :—

(1) The best methods of removal and disposal of dry refuse in India.
(2) ... ... liquid ,, ,,
(3) ... ... excreta. ,,

1. *Removal and Disposal of Dry Refuse.*—Very little need be added to what has already been said on this subject. Sometimes a distinction is made between 'organic' and 'inorganic' dry refuse,* but in practice, with rare exceptions,† the two are intimately mixed. There is no better plan, at present known, for the destruction of the organic matter in dry refuse, than exposure to heat in an incinerator. It is not, of course, really *dry* refuse when brought to the incinerator for it contains a very large amount of moisture which interferes with the process of combustion and special devices are necessary to overcome this difficulty. It now appears, however, to have been successfully surmounted and, if so, there is no doubt that in a few years nearly every town in India of any considerable size will avail itself of this method for the disposal of its dry rubbish. In the smaller towns and villages the disposal will still have to be by incineration or by removing it to a safe distance and spreading it on land, with due precautions, as already described. If sold to contractors as manure,‡ stringent regulations are necessary to prevent the creation of nuisance and pollution of water-supplies.

2. *Removal and Disposal of Liquid Refuse.*—This is a very important and somewhat neglected branch of the

* *v.* McNally, *op. cit.*, pp. 106-7.

† During the destruction of large buildings condemned from age, a large amount of so-called inorganic dry rubbish may be available but this is not common. In such cases the safest plan would be to spread it on land, cover with a foot of earth and leave undisturbed for several years.

‡ In 1885 nearly Rs. 85,000 were realised from the sale of dry refuse in the Punjaub, principally consisting of excreta, however. It is only when excreta are added to dry refuse that it is saleable to any extent.

subject under consideration. Dry refuse and excreta are so much *en évidence* that their removal and disposal is early looked to by sanitarians. To many of these latter in this country, however, the sewage, unless it includes the excreta, seems a small matter. They are so firmly persuaded and grounded in their belief that 'dry' methods are essential for a tropical climate that they overlook or ignore the existence, or at all events the importance of, house sewage. The amount of such liquid refuse that really needs disposal may be faintly realised by a visit to the lines of a native regiment where each house has in front of it a large receptacle sunk in the ground, into which the waste water from the house trickles along an open drain. From the usual condition of the drain and from a knowledge of the habits of the people it may be safely inferred that not more than one-half, at most, of the waste water reaches the receptacle, yet these require emptying every two days, if not oftener, and in spite of the rapid evaporation under a tropical sun.*

At present in most towns and nearly all villages there are two ways in force for the getting rid of this sewage. One is the more general, but hardly more hurtful, plan of simply making no provision whatever for its removal, reliance being placed merely on the absorptive power of the soil and surface evaporation.† The other, and more ostentatious method, is the construction of a series of shallow, and in every way imperfect, open drains, ending nowhere in particular or in a tank or watercourse used for bathing and drinking. And all this is harmless because the sewage does not contain added excreta, or is not *supposed* to! There is no greater error possible. A moist subsoil saturated with organic matter is undoubtedly a favourable nursery for disease contagia and what is more likely than

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* *v.* also note p. 147.

† As illustrated in perfection in the immediate neighbourhood of 90 *per cent.* of the kitchens (*sic*) belonging to the bungalows of the wealthier classes, European and otherwise. *v.* Chap. v. Buildings.

that such a breeding ground should become inoculated with the poison of enteric fever and other diseases.*

It is necessary then to realise clearly that this house sewage is a waste product for the removal and disposal of which definite and sufficient provision must be made. For very small villages or for isolated houses all that is necessary is a well-laid open drain of proper shape and material† leading to a garden where the sewage can be daily utilised.‡ The drains must be kept clean and flushed with water occasionally if necessary. In time of heavy rain the liquid flowing along the drain will be almost pure water and can be safely diverted into the ordinary surface channels or, better still, run on to waste ground. For larger villages and most towns there should be a proper system of such open drains *very carefully laid and constructed, great attention being given to proper gradients.* If necessary, liquid excreta may be allowed to enter these drains but any attempt to use the drains, morning and evening, as a substitute for latrines should be at once punished.§ Having constructed such a system it should be made to end in some spot where the sewage can be harm-

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* Not long ago a lady, resident in an official bungalow at one of the finest hill-stations in India, was attacked with severe enteric fever. On examining the waste water pipe from the bath-room, it was found to open into a brick drain that ran about four feet and then terminated abruptly. In addition, there was no catchwater drain for the water dripping from the hill above so that the ground at the back of the house was always damp. On digging up the soil round the termination of the drain, which latter had apparently 'silted up,' it was found to be saturated and discoloured with greasy organic matter and the stench emitted was fearful. No other cause for the attack could be discovered and it was quite an isolated case. It was almost certainly attributable to the above-noted defective state of things. The general health also, of the other occupants of the house was by no means good. Since the introduction of a proper system of open drains carrying off all rain and sullage water, there has been no further sickness.

† *v.* pl. ix. If cheapness is essential the drains can be built of good bricks laid in mortar, pointed with cement and the whole thickly tarred.

‡ *v.* Chap. v. Buildings.

§ In the case of adults by fining at first with imprisonment on subsequent conviction: in the case of children by the cane. If due notice of such being a punishable offence has been given to all and sundry, there is no earthly reason why punishment should not follow a breach of the rule. It is done with admirable success in military lines, as also under military rule in Burmah, and if the police were compelled to arrest every trans-

lessly and, if possible, usefully disposed of by irrigation or otherwise.* In the largest towns the disposal of the sewage forms part of the question of disposal of excreta and will be considered under the next heading.

3. *Removal and Disposal of Excreta.*—From the description of the various methods of removal and disposal given in the earlier part of this chapter it is easy to gather a general idea of those which are most suitable to this country. For small towns and for villages there is no other known plan of any efficacy save the dry method of removal, with or without admixture, followed by disposal in shallow trenches which are covered in with fresh earth when full. The removal must be *regular and thorough* and the ground where the disposal takes place *frequently inspected* to see that the operations are conducted so as to bring the excrement into contact with fresh earth and to prevent its burial *en masse* in pits.† It is in the case of large towns that differences of opinion as to removal and disposal of sewage and excreta really begin. Are the excreta to be added to the sewage or not? There may be some difference of opinion as to whether open drains are suitable for the removal of waste water, etc.; there is no doubt as to their

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gressor, or severely punished for not doing so, the same degree of prevention in the case of the civil population could certainly be obtained. Various pecuniary penalties can be inflicted for committing such a nuisance in the street, under different Municipal and District Acts, but they are never properly enforced.

* Of course there are apt to be many difficulties in the way of such disposal, and these will only be overcome when the local medical officer or other sanitary authority takes an active and genuine interest in the matter. There are few places in India where prejudice against the use of sewage or excrement as manure will long withstand vigorous and kindly effort: such excellent fertilising material is too valuable to be wasted. In Japan and China the use of human excrement for manure is universal and it is a substance of very considerable pecuniary value.

† As is done at Cawnpore. "Tho pits are about 20 ft. square and 4 ft. deep, and are filled up with the liquid nightsoil, which is left to heat up and ferment in the sun. The ground being of clay, there is very little combination between it and the sewage, which putrifies so freely as to be covered like beer with a head of foam, due to the gas bubbles rising through it. The stench is indescribable and lasts at least two years. The residue, when dry, is sold to cultivators as poudrette, having lost the greater part of its fertilising powers in the gases of decomposition. Wallace, *op. cit.*, p. 161.

entire unsuitability for the removal of sewage *plus* excreta. Hence it is first of all necessary to compare together the dry and wet methods of removal and to weigh their relative advantages and disadvantages.

Numerous objections have been urged from time to time against the plan of having a system of underground sewers connected with houses by means of pipes leading to water-closets, etc. Every one of these objections having any weight has reference to *faulty construction.* (1) The system is defined as a network of underground channels containing foul, decomposing material, in immediate connection with dwelling-houses, so that the house pipes act as ventilators along which the poisonous sewer air can and does pass into the interior of the houses. Now, such a definition of a sewerage system was and is only too true for certain towns in Britain and elsewhere, but is about as accurate in the case of a modern well-sewered town, on the separate system, as the ordinary definition of a volcano.* There is certainly an underground series of channels in mechanical connection with houses, but efficient means are taken to prevent the backward passage of sewer air and, in any case, the sewage is so quickly removed that decomposition proceeds but slightly ere the sewage reaches the outfall. Hence, as before explained, the air† in a modern sewer is wonderfully pure. (2) It is urged that at any time the pipes may break or the jointing prove defective, the surrounding soil becoming polluted as a consequence. Even with proper pipes and good foundations and workmanship such an accident *may* happen occasionally, but, under systematic inspection it would soon be detected, sewers being now engineered specially to facilitate such inspection. (3) The water supply is said to be in danger of contamination. The various ways by which this might

* *viz.*, a 'burning mountain giving forth flames and smoke.'

† Some insist upon careful distinction between sewer air and sewer gas. Of course the latter implies the gases given off during decomposition of sewer-slime, etc., and these in their turn help to render impure the natural sewer-air.

take place cannot be described in detail,* suffice it to say that here also such an occurrence could only be due to faulty construction or a breakage in the pipe-sewer coupled with the use of a shallow well as a water supply.

These then are the objections so called. There are one or two other points requiring attention. Where there are water-closets in connection with a sewerage system, a large and unfailing water supply is necessary to flush the closets and to keep the traps sealed. Without this the system is unworkable. Again, the use of water-closets means so much extra fluid added to the sewage and requiring disposal. Suppose these are used once daily by a population of 30,000, with an average flush of two gallons only, it will be seen that about 60,000 gallons of fluid are added to the daily sewage discharge for disposal at the outfall. For the same reason, the original cost of the system will be greater than where the sewers simply carry waste water. Finally, if the town is low-lying, so as to prevent the sewers being laid with good natural gradients, the sewage must either be pumped or the Shone system adopted. This means considerable extra expense.

In favour of the water-carriage system is the important fact that sewage and excreta are thereby removed as nearly *immediately* as may be. Sewage water must be removed anyway and the addition of the excreta and extra water from the closets does not perceptibly add to the impurity whilst the initial extra cost is more than compensated by careful construction and the saving of plant and labour in removal of excreta by dry methods.

Coming now to dry methods the most obvious advantage is *not* the non-necessity for sewers of any sort, but that no system of *closed* sewers is necessary. In addition the amount and permanence of the regular water supply is not so important.

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* The commonest cause of such a serious mishap is the wilfulness of builders in leading an overflow pipe into the sewer instead of making it end in the *open air* just beyond the outside of the wall.

The chief disadvantage is *delay in removal of the excreta*, a small matter perhaps, in the case of healthy people, but of great importance in diseases like cholera and enteric fever. If admixture with earth before removal is practised, as is frequently the case in this country, the carriage and storage of a large quantity of earth is a very expensive matter, as also the removal by hand or cart of the mingled earth and excreta.* Æsthetically it is objectionable on the large scale compared with a *good* water-carriage system.† Suitable earth is not always obtainable, and besides, the amount of fæcal matter to be removed from a large town is so enormous that the town would become surrounded after a time with buried deposits of filth.‡ Finally, and most important of all, it is only a partial system and leaves entirely untouched the question of disposal of sewage and the whole or greater part of the liquid excreta.

It remains, then, to consider what are actually the best methods available *in this country*. At once there arise a number of objections to be considered and difficulties to be overcome, due to two great and ever present factors, *viz* :—the *tropical climate* and the *existence of caste*.

The climatic peculiarities are principally those due to a

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* Save in the case of isolated institutions, like jails, where free labour is obtainable, and which are not comparable to towns.

† In the otherwise admirable work by McNally, so often referred to, there are one or two points in this matter that require notice. In favour of a dry system of latrines he says that "foul water not containing latrine waste being so inoffensive may be passed into ordinary drains," *i.e.*, into surface drains, which empty themselves into the nearest watercourse or allow their contents to sink into the soil. This, as before stated, I believe to be a dangerous error. Again he says "the same earth can be used over and over again after drying, and the return latrine carts would carry earth instead of going empty." I have before (p. 139) alluded to the fact that the same earth *can* be used several times so far as its deodorising powers go. It is extremely doubtful, however, whether such a plan is advisable, and certainly the same carts should not be used for removing excreta and bringing fresh earth. "Quite recently," says Sir William Moore, "Surgn. Capt. Nichols, Surgn. Capt. Battersby, A.M.S., and also Dr. Hare, of the Brisbane Hospital, Queensland, have condemned the dry-earth system (B. M. J., 1890); especially when, as the officer first-named remarks, the cart which takes the mixture of earth and fæcal matter to be buried brings back dry earth for use." Trans. VIIth Internat. San. Sci. Congress, vol. xi, p. 27.

‡ "As military stations are now being surrounded." (Moore, *loc. cit.*)

powerful sun, and alternating seasons of drought and heavy rainfall, with occasional failure of the latter. In the hot weather, from March to the middle of June, there may be barely sufficient liquid to run in the drains, whilst in the wet months the drains may be running full and carrying pollution to every neighbouring water supply. Again, the hot sun causes the water of the sewage to evaporate rapidly and the sewage itself to undergo rapid fermentation, so that most offensive odours, and probably micro-organisms and other minute organic particles, are given off. On the other hand, the heat causes desiccation of the solid refuse matters so that they become 'mummified' or dried up and do not give rise to a nuisance. This, certainly, is apt to be but a delaying of the evil, for when the rain comes, all refuse lying about speedily begins to decompose and putrefy. Lastly, if from long continued drought the water supply should fail, any system of closed sewers becomes an unmitigated evil.

The existence of caste with its peculiar train of social beliefs and customs makes this problem of ten-fold greater difficulty than it would otherwise be. If indeed caste prohibitions, as believed in and practised, were thoroughly rational, and pollution really meant pollution, the difficulties of framing sanitary measures and of inducing the people to live sanitarily would not be nearly so great.* In most districts in India, the caste population is more or less completely at the mercy of the sweepers (*mehters* or *toties*) whose occupation is hereditary and each of whom will only work in certain houses, perhaps situated far apart.† Again, there are many other social customs, such as the

* "The sanitary appliances for the removal of the refuse of the population by water-carriage in India must not only prevent the waste of water, but must be of such a character as not to even splash with water the person using them, for fear he is polluted; yet these same natives ordinarily bathe in common, and use waters for all purposes of the vilest character, to which there has been access of all those matters which are looked upon as a cause of pollution to the particular individual when he has to use sanitary appliances within his own residence." (Baldwin Latham. Trans. VIIIth, Internat. San. Sci. Congress, vol. xi, p. 201.)

† With regard to this difficulty, there are many graphic descriptions in the volume above quoted.

segregation of the women in special quarters, the almost universal custom in small towns of going outside in the morning to any piece of unoccupied ground, *e.g.*, the bed of a dried-up tank, for the purposes of nature, etc., etc., which make it extremely difficult or impossible to carry out the removal of excreta thoroughly and systematically.

Like other sanitary problems, this must be solved differently according to the nature and circumstances of the population concerned.

Isolated houses and very small villages.—In this case the best means at present available is the setting aside of certain pieces of waste ground, remote from the water supply, as a site for moveable latrines consisting simply of screens or *taties* surrounding shallow trenches.* Any excreta passed in the houses must be carefully removed and buried in these trenches. Vegetable and other house refuse should be destroyed by burning in the fields or spread on the ground and ploughed in. There should be a good, *packa* built open drain to remove all waste water, and urine if necessary, from the neighbourhood of the house.†

Large villages and small towns.—These are perhaps the most difficult places of all in which to carry out a good system of conservancy. If some inexpensive and simple form of incinerator could be invented, as no doubt it will, all solid refuse should certainly be disposed of by fire.‡ The liquid waste should be conducted by a good series

* Or the jungle itself may be preferable as well as customary, *v.* Moore, *loc. cit.*, p. 28, line 4 from bottom. The ancient Israelites were directed (Deut. xxiii, 12-14) to cover the excrement, when passed, with earth. It is a pity that such a custom does not obtain in India. The spectacle presented to the passer-by outside most towns in India, morning and evening, is insanitary and disgusting to the highest degree.

† *v.* p. 149. For further details on this subject *v. post.* Sanitation of Towns and Villages.

‡ Since writing the above, I see advertised the "Silchar Patent Cinerator and Rubbish Furnace," *especially suited for small communities.* It is said to cost about Rs. 400 only and to burn and completely destroy all kinds of organic refuse from gardens, stables, kitchens and latrines, also the bodies of dead cattle, both during monsoon and dry weather. It has been adopted by the Assam Government and several municipalities, Simla

of open drains to a proper outfall for disposal by irrigation of land. If possible, the solid excreta, whether passed in public latrines* or in private houses, should be disposed of by drying in a special part of the incinerator and used as manure, or else removed direct to the fields and buried in shallow trenches, the land being shortly afterwards ploughed and cropped. The urine, if the drains are well-made and frequently cleaned, may pass into the open drains.

Jails, Hospitals, Lines, Cantonments, etc.—In such cases as these the conservancy is usually easier and much more thorough: the great difficulty is the question of disposal. The earth system, with admixture before removal, is almost universal but is by no means perfect. At present there is no efficient substitute. In time to come the destruction of refuse matter by small and easily-managed incinerators will probably be the favourite method. All liquid should be utilised for cultivation in the case of jails, cantonments, etc. In hospitals it should enter the general drains of the town or be removed to a suitable spot by hand.† In this latter case also there should always be abundant means of thoroughly *disinfecting* the motions in cases of enteric fever, etc., *under responsible supervision.*

Large Cities.—In all towns of any size there is only one proper way of disposing of the dry refuse or ordinary

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Silchar, Kohima, Naraingunj, etc. It is certainly worthy of trial. J. Wallace, C.E., Bombay, is sole agent for India (excepting Bengal and Burmah).

* Moore (*loc. cit.*) considers that the publicity and unavoidable odour of public latrines is a drawback to their use. It is certainly so, but these are lesser evils than others. Again, he says, the value of land makes the reservation of special plots difficult and there is a complaint of want of privacy here also. But surely the value of land is not so great as to prevent the town or village collectively paying a small rent. As regards the complaint of want of privacy behind tatty screens the experience of the writer is that in very many instances the people seem to go out of their way to choose the most conspicuous place possible.

† At the General Hospital, Madras, the sullage water used formerly to be discharged into the already polluted Cooum backwater. It is now, under arrangements made by the present S. M. O., Bde-Surgn. Lt.-Colonel W. Price, M.D., utilised for irrigating the grounds of the hospital, which are thus kept perpetually green and neat. There is no sign of a nuisance, and the amount of grass that is grown and cut for forage is considerable.

rubbish and that is by fire. *The* question to be decided is whether there should be a system of closed sewers or not. Until a town has got a thoroughly abundant and permanent water supply the answer must be in the negative. If the town lies on a good natural slope the laying of sewers is easy and a comparatively simple matter. If, on the other hand, the land is very flat it becomes necessary either to pump the sewage from a lower to a higher level or to adopt Shone's Hydro-Pneumatic System. Again, how are the rain and subsoil water to be disposed of? Certainly not by admittance to the ordinary sewers. Whatever system be adopted it should be partially or completely *separate*. If an old system of brick sewers exists it may be made to carry off the storm-water and drain the subsoil. If not, special provision must be made for draining the subsoil. This is not always an easy matter, but is quite essential for the health of the population in many Indian towns. "Drainage is not, however, the universal panacea which some consider it to be. Subsoil drainage is not applicable to those sandy countries where only a few inches of rain fall, for the sand immediately absorbs the rain like a sponge, and although it remains damp and cold a very short distance from the surface, this would not be much altered by drainage, the moisture not being sufficient to escape from the holding sand by oozing. Surgn.-Genl. Cornish, C.I.E., has also pointed out that subsoil drainage is not applicable to certain districts in the Carnatic, where they do not suffer from too much moisture, but from excessive dryness of the soil. During the long period of drought, subsoil pipes become blocked by deposits of ants, lizards, rats, etc., so that when they are really required, no water flows through them. This it may be said is a matter of supervision, and so it is to a considerable degree. But to ascertain the patency of any large extent of subsoil drainage is no easy matter, and deposits of the nature mentioned occur very suddenly. As a matter of fact when the Indian monsoon bursts, and heavy rain falls, many subsoil drains overflow." "The greater my experience," says Dr. Simpson, the

Health Officer of Calcutta, "of the effects of the network of underground drains in busties, the greater is my distrust of their utility and freedom from danger. It would be safer and more conducive to the health of the busties to restrict underground drains to the broad roads, which should intersect." "All tributary drains," continues Sir W. Moore, "should be open, or should be covered with moveable iron gratings, which would ensure the condition of the drains being readily seen, while the drain being exposed to the influence of the sun* and air, injurious gases would not be elaborated."† A large amount of storm water can be removed by surface drains, ere it sinks into the ground.

In time to come the inhabitants of the larger cities will become habituated to the use of water-closets‡ and abuses and prejudice be done away with. The result will be a large saving of labour and a considerable gain in health for the population. Where house connections and water-closets are not desirable, then the excreta, liquid and solid, should be removed in air-tight receptacles and emptied at special openings, morning and evening, into the main sewers. The waste water can be got rid of by good open§ or closed drains, connected, in either case, with the sewerage system. The following extract is noteworthy as being written by a native and medical graduate of this country.‖ "In the case of the larger towns, where sufficient money and an ample supply of water are available, the water

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* It has been proved that direct sunlight in the presence of oxygen, has a distinctly retarding and even destructive influence on micro-organisms of various sorts. This fact may hereafter be proved to have important bearing in reference to the use of open drains for sullage water, etc.

† *v.* Trans. VIIth Internat. San. Sci. Cong., vol. xi, p. 31.

‡ Not necessarily water-closets in *every* house but probably trough-closets for common use in the poorer parts of the town. *v. post.* Sanitation of Towns.

§ Of course, if open drains are used it means that a large amount of storm water will gain access to the sewers. In such a case the only method in this country is to 'intercept' the storm water as much as possible and discharge by a separate outfall (*v. ante* p. 171).

‖ K. V. Dhurandhar, L. M. and S., Medical Officer and Superintendent of Vaccination, Baroda, (*v.* Trans. VIIth Internat. San. Sci. Congress, vol. xi, p. 141).

carriage system of removing excreta is the best. The experience of that system in Calcutta and Bombay, though even now the sewers are incomplete, justifies the conclusion that water-closets of simple construction best suit the prejudices of the natives of this country. Natives have an aversion to the person of a scavenger, and suffer in consequence a good deal of filth to collect in and about their dwellings. The system of removing excreta by waterflow in underground drains and sewers is the cleanliest and most economic in the long run. It is pleasant to find that the foolish opposition that once threatened to be formidable against the system of underground drains is fast dying out. It had its origin in overdrawn descriptions of outbreaks of typhoid from badly constructed sewers in England which now and then appear in the newspapers. Some of the Native States, such as Baroda and Hyderabad (Nizam), and some municipalities, have wisely voted large sums for the sewerage of their towns. The designs must be made only by sanitary engineers with the most recent drainage experience." With the above quotation all whose knowledge of the subject is up to date must agree. Regarding the disposal of the refuse matter, the products of the incinerators may be utilised as before described;* the sewage should certainly be disposed of by irrigation, combined with intermittent filtration if necessary, or, in the case of towns situated on the sea-board, if no suitable land is available or if there are other obstacles to its utilisation in this way, by discharge, at a carefully selected spot,† into the sea. In all drainage schemes of any magnitude it is absolutely necessary for true economy and efficiency that the very best advice and personal supervision be obtained.‡

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* *v.* pp. 145-6. † *v.* p. 177.

‡ This subject cannot be considered in further detail here. The latest contribution to it will be found in Wallace's 'Sanitary Engineering in India,' chaps. IV—VII inclusive. He shows that the chief difficulties to be overcome in applying a complete sewerage system, as in common use in England, to an Indian town, are (1) the 'human factor' of ignorance and prejudice; (2) the failure of siphon traps owing to loss by evaporation and the throwing of improper articles into the down-take pipe

DISPOSAL OF DEAD BODIES—HUMAN.

In this country there are various ways in force of disposing of dead bodies. Amongst the Hindus, who form by far the larger portion of the population, disposal by burning is the more usual method. In certain special cases earth or water burial is used instead. Europeans, Mahommedans and Burmese bury their dead in the ground; Parsis, in Bombay at all events, expose the bodies to be eaten by vultures in the Towers of Silence.

Cremation.—Of these various practises there is absolutely no doubt that cremation is by far the most sanitary and is equally preferable on æsthetic grounds. But it must be thorough cremation and not a merely partial destruction of the soft structures. If properly carried out, the whole body should be reduced to a fine powder which, being of a purely mineral nature, is clean and harmless and can be disposed of in accordance with the religious scruples of any particular sect. One* who has studied this subject carefully and has had much official experience of earth burial in England writes thus, with reference to the introduction of cremation in that country:—"I am so deeply convinced that cremation should be substituted for it [earth burial] for many weighty reasons, that I feel it necessary for me to give a few of them:"

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on which the siphon is situated; (3) the accumulation of a peculiar and objectionable 'silt' in the main sewers, very troublesome to remove; (4) the difficulty of ensuring that the discharge of sewage at the outfall into a river shall take place well into the stream during the period of smallest volume of the river. He suggests several outlets to suit various states of flood, the lower ones being dug out once a year if they become silted up. This latter idea, of course, is comparable to the in-take pipes which are sometimes constructed at different levels, (in place of a water-tower) in water reservoirs, and used in turn according as the water level in the latter is high or low. Mr. Wallace is a strong advocate for the use of iron pipes as sewers and it is possible that they may be adopted to a considerable extent, at all events experimentally. Indeed the whole question is still in an experimental stage, but of the *ultimate* adoption of three things in most towns there can be little doubt, *viz.*, *incinerators* for the destruction of all dry refuse or *cutchra*, properly built *closed sewers* (with or without house connections) for the removal of all liquid refuse (and possibly excreta as well), and the disposal of sewage by *irrigation* (with or without intermittent filtration).

* Boulnois, *op. cit.*, p. 410, altered.

(1) Nothing can be more unsanitary or dangerous to the living than the burial of the dead. This has been enlarged upon over and over again by men who have well studied the subject and are competent to give an opinion, and to that opinion I add my testimony.*

(2) Nothing can be more loathsome and degrading to the dead bodies of our friends, or more revolting to our feelings, than the horrible practice of placing the remains of those we love in the soil of a churchyard or cemetery, to be devoured with other bodies by worms.

(3) In placing a dead body under ground we can never be sure how long the remains will be left undisturbed, a new road or railway will soon destroy all traces of its resting place.

(4) In the event of friends or relations dying abroad or at a distance their remains cannot be sent home for burial except at great expense: on the other hand, cremation would reduce the body to a few

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* In 1843 when a parish church near Stroud in Gloucestershire was in process of re-building, the superfluous soil of the burial ground was disposed of for manure (!) to the villagers, and the result was nearly a decimation of the place. The outbreak of the plague in Egypt in 1823 was traced to the opening up of a disused burial-ground about 14 miles from Cairo, and thousands perished in consequence. An investigation was made in the cemeteries of Rio de Janeiro, about five years ago, upon earth taken about spade deep from graves where victims of yellow fever had been buried some twelve months previously, and this soil was found to contain 'myriads of microbes,' self-same with those present in persons stricken with the same pest at the time of the excavation. A healthy guinea-pig was incarcerated in a space over which earth taken from a grave was sprinkled, and in five days the animal was dead, its blood being found to be 'literally crammed' with the germs of the disease in various stages of growth." Boulnois, *loc. cit. supra.* "Some years ago a body of prisoners were employed in making a road in the Guntoor district, and in cutting away the soil, they came upon the remains of a number of persons who had died of cholera in 1838; cholera immediately broke out among the workmen. A party of coolies employed on a railway cutting near Salem, opened a spring of very clear water. Those who drank of it were seized in a few hours with cholera of a very severe type. In this instance the railway cutting passed through an old burial ground." Sir W. Moore, *v.* Trans. VIIth, Internat. San. Sci. Cong., p. 27. And so on, the list might be extended *ad infinitum.*

silvery ashes which could easily be brought home and secured on arrival in a suitable and safe position.

(5) Cremation is the most respectful and beautiful manner for the disposal of dead bodies, as fire is the most perfect purifier and type of purity with which we are acquainted, and need not alarm (on religious grounds) any more than the practice at sea of lowering dead bodies overboard.

(6) Cremation is merely a *more speedy means of burning a body than burial,* decomposition being only a very slow and loathsome combustion.

(7) A large amount of valuable land is rendered useless for building or agricultural purposes.

(8) The expenses of earth burial are proportionately very large. Public crematories for the different sects or castes should be instituted. For a very small cost, sufficient heat could be maintained to consume almost any number of bodies, whilst the present great expense of maintaining large cemeteries would be dispensed with.

The only objection of any weight* ever urged by the opponents of cremation is the difficulty of detecting cases of poisoning. This is certainly an objection that is worth considering. In England it could be met by instituting a scientific and independent enquiry as to the cause of every death which occurs. This is so much required at the present day for the sake of the public health, that even if cremation is never introduced, it should be at once en-

* Some have pretended that in burning bodies the soil is deprived of a natural manure! Against this are the facts that cemeteries are not used and are not meant to be used as farms, and secondly, that the very existence of large cemeteries means valuable land diverted from its natural use. *v.* (7) *supra.*

forced, so that those who have charge of the public health could have exact and reliable knowledge of the causes of all the deaths throughout the United Kingdom, and thus obtain such valuable information as would greatly assist in the daily fight to subdue and overcome deaths from preventable causes.* Several large crematoria have been built in England and it is only a matter of time till the practice becomes general.†

In India, as has been stated, the burning of bodies is no new thing, but, with rare exceptions, cremation in its proper sense is almost unknown. Poverty no doubt is the chief reason for such a state of things and this can only be remedied either by public crematories under municipal control or else under immediate control of the various castes with general supervision of the municipal authorities. The sites for burning-grounds should be most carefully chosen so as to be distant from all dwellings and sources of water supply. Cremation, in large towns, should be conducted in the absence of air in proper furnaces, the process being essentially one of destructive distillation, as in a closed retort. In such a furnace an ordinary adult body is destroyed in about two hours, the resulting mineral ashes weighing only about three pounds. For small towns and villages efficient burning on a pile of wood or with cow-dung cakes may be permitted at the

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* The danger of concealment of cases of poisoning is much exaggerated with reference to Great Britain. The extra number of cases that would escape detection if cremation was adopted generally, would be but a very *slight* increase on the number that escape under present conditions. The above proposal to carry out a scientific examination into the cause of every death would not be easy to carry into practice, but is now being considered in England. Anyway the good of cremation far outweighs any possible evil.

† Some of the sentimental objections urged by the opponents of cremation are most curious and amusing, but cannot be quoted here. They are strictly analogous to many of the so-called religious scruples advanced in this country to resist any sanitary innovation and owe their origin to the same fountain heads of ignorance and superstition. The great argument formerly used and one which still has weight amongst a certain order of persons, was that if the body was destroyed by fire how could it be raised again at the Judgment Day? Such depths of ignorance and superstition in a country like England should make us more charitable towards the beliefs of others.

selected site and under supervision.* The use of such a place as the bed of a dried-up river should be strictly prohibited.

Earth burial.—In this case even stricter precautions are necessary than in the case of cremation.† The selection of land suitable for a cemetery in not always easy. "The soil of a cemetery should be of an open porous nature, with numerous close interstices, through which air and moisture may pass in a finely divided state freely in every direction. In such a soil decay proceeds rapidly, and the products of decomposition are absorbed and oxidised. The soil should be easily worked, yet not so loose as to render the work of excavation dangerous through the liability to fall of earth. It should be free from water or hard soil to a depth of at least 8 feet. If not naturally free from water, it should be drained if practicable to that depth: to this end it is necessary that the site should be sufficiently elevated above the drainage level of the locality, either naturally or, when necessary, by filling it up to the required level with suitable earth. Loam, and sand with a sufficient quantity of vegetable mould, are the best soils; clay and loose stones the worst. A dense clay is laborious to work and difficult to drain; by excluding air and moisture it retards decay, and it retains, in a concentrated state, the products of decomposition, sometimes to be discharged into graves opened in the vicinity, or sometimes to escape through cracks in the ground to the surface. A loose, stony soil, on the other hand, allows the passage of effluvia."‡ Further, the cemetery must be situated con-

* "It is the duty of Municipal servants at the burning grounds to see that the corpses are completely consumed, and that in those cases where the ashes are not carried away, they are prevented from accumulating in heaps, to the inconvenience of persons attending following ceremonies." (Jones, *op. cit.*, p. 87). The ashes are buried in some part of the ground. The cost of cremation in Madras varies from Rs. 4 to Rs. 1-6. The average price is Rs. 2.

† "Speaking broadly, the effect of the proximity of a burial ground upon health is the same as that of any other accumulation of putrefying animal matter."—Whitelegge, Hyg. and Pub. Health, p. 204.

‡ *v.* Eleventh Ann. Report, Local Government Board.

veniently, if possible; certainly not near any source of water supply nor near any inhabited spot.* The ground must also be firm and not exposed to the danger of land-slips, flooding by storm-water or encroachment by a river or the sea.† In some places it is very difficult to find a place at all suitable for inhumation, and in some it is quite impossible.‡

Many sorts of material are used as coffins for enclosing the dead body in Europe. Of these the worst is lead, the best thin wood, wicker-work or *papier-mâché*.§ In the case of noble or wealthy people, their bodies, in former times, were buried in brick-lined graves or in graves dug in the church itself or in underground rooms connected with the church.|| Such practices are all equally insanitary and opposed to the first postulate of earth burial, which is that *the body shall be so circumstanced after death as to be dissolved into its elements as speedily and inoffensively as possible.* These conditions can only be fulfilled by the choice of a suitable soil, as described above, a grave of proper depth,¶ a thin, easily-destructible coffin and the growth of suitable plants in the immediate vicinity. Above all, over-crowding, a constant evil in most town grave-yards, must be absolutely prevented.

The changes undergone by the human body buried in

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* Above all, not on an elevated site from which the foul subsoil water can reach and contaminate a tank, well, or the foundations of dwellings situated at a lower level.

† Every one of these conditions has been many times violated and it is by no means easy to fulfil them all. In some cemeteries choice is made, apparently, of the *most unsuitable* piece of ground simply because it is prettily situated or near the town !

‡ *e.g*, at Kalémyo in Upper Burmah it was found quite impossible to dig a grave *anywhere* (!), the whole ground being completely water-logged during the rains.

§ Layers of paper compressed by machinery into a wood-like material.

|| Vaults, catacombs, etc.

¶ Not less than six feet deep, nine long, and four broad for adults, so as to surround each body with clean earth. Under the Madras Municipal Act there must be 5 ft. between the ground level and the upper surface of the coffin and a margin of 2 ft. round the grave. The present M. O. H., Dr. J. Nield Cook, makes the burial-ground peons test the depths of the graves by means of 6 ft. staves which are pushed through the ground.

earth are the same as take place in any decaying organic material, *viz.*, through the agency of various animals, micro-organisms, and plants, the destructive process is carried on. At first carbon dioxide, carburetted and sulphuretted hydrogen, ammonia, nitrous and nitric acids and other complex and fœtid products are evolved, which are eventually oxidised into simpler combinations. The salts go to enrich the soil and are used up by plants or dissolved and removed by the ground water. The harder structures, especially the mineral framework of the bones, remain for long periods unaltered. When bodies are buried in unsuitable soil, *e.g.*, clay or peat,* they may remain unaffected for a long time and in some cases are transformed into the curious fatty substance named adipocere.†

In India there is the greatest need for speed in burial on account of the rapidity of decomposition and, except in really *cold* weather, no dead body should remain unburnt or unburied for more than twenty-four hours at longest. It should certainly be made illegal to bury the bodies‡ of cholera patients, even if disinfectants, so-called, are used, and proper arrangements for cremation of all classes and sects should exist. Such a furnace should consist of a closed chamber or retort in which the body is placed and and the whole heated to 1,500° F. In one hour the operation is complete. Whenever any place has been used as a burying ground, temporary or permanently, for one or more people, the spot should be suitably and distinctively enclosed, and this both on hygienic and social grounds. Such a practice as simply throwing out cholera bodies or others on to waste ground or into water should be made a crime and the offenders punished by imprisonment.§

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* *v.* p. 110. † *v.* Works on Medical Jurisprudence.

‡ As also the excreta.

§ The extraordinary supineness of the authorities, municipal and otherwise, in this matter seems almost inconceivable to those who have not seen it. The author remembers, in Ganjam, seeing a dhoby washing clothes in a nullah, about fifty yards from a floating cholera body, whilst the peon stationed there to prevent such an occurrence, carried on a leisurely conversation with the dhoby!

Dead bodies being carried through the streets should be decently covered up from head to foot and it should be illegal to expose them.*

Water Burial.—The custom which prevailed and still prevails, of carrying the dying to the banks of sacred rivers and, after death, partially burning the body which is then thrown into the river,† must formerly have been a most fertile source of disease. It is a thoroughly insanitary practice and should be strictly prevented. When the cremation is properly carried out, and the body reduced to mineral ashes, there is no objection whatever to the ashes being scattered on the water.

Burial at sea is but rarely resorted to save when death occurs on boardship. It is in many ways preferable to earth burial as ordinarily carried out, and far better than the exposure of bodies to be eaten by loathsome vultures. When a body, wrapped in sail-cloth and with heavy shot attached to it, is dropped over the side of a ship in mid-ocean, it is practically certain that it sinks with comparative rapidity to the depths below and, becoming embedded in the 'ooze' formed of the calcareous coverings of myriads of marine organisms, has a more suitable and more inoccuous resting-place than in any town cemetery. In any case it is better that the corpse, the worn-out earthly covering, should be rapidly and harmlessly disposed of under water than left to decay slowly and, it may be, spread disease, a few feet below the earth's surface.

Many other methods have been, and are, in force amongst different tribes and nations, for the disposal of their dead, and the various rites and customs form a most interesting chapter in Comparative Ethnology. Amongst these are embalming, as practiced by the Egyptians under an erroneous idea of the connection between the body and

* It is illegal to do so under the City of Madras Municipal Act (*v. post.* Sanitary Legislation) but, like most other Municipal enactments, no proper attempt is made to enforce it.
† Or, what is worse, throwing the body into the river direct.

soul after death, exposure to wild animals or to dogs specially trained to devour the corpses, exposure on platforms or in trees, etc., etc., all of which are opposed to true hygiene and most of them utterly barbarous.*

DISPOSAL OF DEAD BODIES—LOWER ANIMALS.

This subject is only liable to assume important proportions under one of two conditions, *viz.*, an outbreak of contagious disease amongst a particular class of animals, or during war or famine time.

Epidemics.—At such a time, if proper precautions for the disposal of the dead bodies of animals are not taken, a very considerable increase in the spread of the disease coupled with a dangerous nuisance to human beings is apt to occur.† In the case of an outbreak of anthrax it is of especial importance that the bodies of all horses, etc., be

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* The following extract concerning the burial of Sannyâsi Brâhmans is taken from the interesting and accurate work of the Abbé Dubois, 'A Description of the People of India.' After preparatory ceremonies, "the body is placed in a sitting posture, cross-legged, in a large basket; which is suspended with straw ropes upon a strong pole of bamboo and carried by four Brâhmans. They proceed, without noise or tumult, to the trench which has been prepared on the bank of the river, if there be one in the neighbourhood. It is dug so as to resemble a well, about six feet in depth, and is filled one-half with salt, on which the body is placed, in the posture that has been described. "It is then covered up to the neck with the salt, which they press closely all round, so as to keep the head immoveable. This is succeeded by the strange ceremony of breaking cocoanuts upon the head of the deceased, which is continued till the skull be quite shattered; after which, more salt is thrown into the pit, and the head covered out of sight. Earth is then accumulated over the trench, to the height of several feet; and upon the heap so raised a *Lingam* is erected." The presiding Brâhman then "collects all the bits of the cocoanuts which were broken on the head of the deceased, and distributes them amongst those present, who eat them as a sacred and well-boding morsel." *v.* p. 265, *et seq.* The bodies of all other Brâhmans are, of course, burnt, not buried.

† The writer has seen the most fearful nuisance and danger caused by such an outbreak amongst buffaloes in Burmah. Along the river banks the animals lay dying or dead in great numbers whilst crows, kites, adjutant birds, dogs, etc., attacked them before death had actually taken place and after. The dead bodies lay about amongst the villages and floated in scores down the rivers Mitthya and Chindevin, decaying as they went. On these dead bodies, the Burmese, who will eat any thing, feasted. The smell, etc., was most disagreeable, and destruction by ordinary fire most difficult. I have known Burmese eat a miserable, diseased pony; also take the body of a self-dead deer out of the river, as it floated towards them, and shortly after breakfast off it! In the same way the *chucklers* and other low-caste people in India will eat almost anything, horse meat being a favourite morsel.

at once completely destroyed by burning. Burial is quite impermissible. Indeed, as a general rule, it may be said that *destruction by fire* is the only safe and proper means to be adopted in all cases. Great vigilance is necessary, especially in Burmah, to prevent the bodies of animals dying of disease from being used as food. The ordinary rubbish incinerators, which will doubtless soon come into general use, will be quite sufficient for the destruction of the bodies.

War and Famine.—Under these circumstances even greater neglect is liable to ensue, for people are disheartened and will not take the trouble to do anything save what is an absolute necessity. The proper disposal of the dead bodies of the horses, etc., as well as those of human beings killed in war is a most difficult thing, and depends on many varying factors. Various devices have been tried.* If no special means are available, the only plan is to issue peremptory orders for proper earth burial to be carried out with the least delay possible in every case; and to take means to have the order carried out effectively. In future wars between civilised (*sic*) countries, cremation will almost certainly be the method of disposal for both human and other bodies as well.

Famine in India raises a peculiar difficulty in many districts, inasmuch as the people, though starving themselves, will not eat the flesh of the cattle dying from starvation, neither will they bury the bodies. The local sanitary authority should see that the dead bodies of animals are buried with due precautions, or better, burnt completely.

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* *v*. Parkes-Notter, pp. 394-5.

CHAPTER V.

BUILDINGS.

INTO this subject it is impossible to go in detail here; all that can be attempted is to indicate the *principles* which must be borne in mind if buildings are to be suitable for human occupation, and to note some *practical points* to which special attention should be paid. It must be carefully remembered that in India and Burmah the actual construction of dwellings is almost universally done by ignorant native workmen upon whom the unwritten rules by which their forefathers worked are equally binding, and this in spite of official 'supervision.' The latter is often extremely perfunctory and is perforce carried out in many cases by men who have never had opportunities of seeing first class work. This state of matters is gradually being remedied, but the mass to be leavened is out of all proportion to the amount of leaven available.* Things being so as regards official buildings, it can easily be imagined how much worse they are with respect to houses built purely as a commercial speculation. It is not to be denied that in England the same charge of greed on the part of speculative builders, without the possible excuse of ignorance, holds perfectly good, as the rows of 'jerry-built' houses in the suburbs of London and other large towns, only too clearly show. The poorer classes being the chief sufferers in both countries, it is the duty of the municipal authorities (some of whom, however, are the worst offenders), to act upon

* Many volumes might be filled with accounts of the extraordinary and perverse blunders made under the very noses of so-called supervisors. The amount of money spent annually on alterations and re-construction, through originally defective work, is enormous. A certain amount of this 'pulling down and building up' is, it is to be feared, somewhat intentional and follows apparently as a necessary sequel to 'estimates,' and 'contracts.' It is probable that here, as in other cases, an increase in the number of high-grade public works officials, with consequent more effective supervision, would prove to be the truest economy.

the advice of their sanitary advisers in prevention or mitigation, so far as possible, of these evils, and to enforce rigorously the utmost penalties upon the offenders.*

The extent and power of epidemics in former ages are largely to be attributed, amongst numerous other predisposing causes, to the very imperfect nature of the dwellings occupied by the mass of the people.† Then, as in India but a few years ago, the nobles and grandees occupied palaces and forts whilst all below them were housed in miserable hovels crowded together and surrounded by damp and filth. Even now it cannot be said that things are much improved in Indian towns.

With reference to the influence on health necessarily produced by such defective conditions of living, an eminent authority‡ has thus written: "Ill-contrived and closely-packed houses, with narrow streets, often made winding for the purposes of defence; a very poor supply of water, and therefore a universal uncleanliness; a want of all appliances for the removal of excreta; a population of rude, careless and gross habits, living often on innutritious food, and frequently exposed to famine from their imperfect system of tillage,—such were the conditions which almost throughout the whole of Europe enabled diseases to attain a range, and to display a virulence, of which we have now scarcely a conception.§ The more these matters are

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* If anyone built a ship so carelessly that it capsized immediately after leaving harbour, or sold a gun with a barrel that burst on its being fired for the first time, enquiry would certainly be made and the offender probably punished by a heavy fine or imprisonment. On the other hand a builder may build a house which is nothing more than a death-trap, and will consider himself aggrieved if his tenant should dare to get ill and die as a result of its faulty construction.

† A favourite argument with the opponents of hygiene is that, in spite of such a state of things, countries like England were enabled to produce and rear a splendid class of men, who were the pioneers of discovery and the heroes of battles throughout the world. Such a fallacious argument hardly deserves notice. It is merely an example of the well-known law of 'the survival of the fittest' and entirely leaves out of account the enormous death-rate and amount of preventable sickness.

‡ The late Edmund Parkes, *v.* Parkes-Notter, p. 220. So also many other writers—Froude, Green, Kingsley, Simon, etc.

§ Those, however, whose memories go back to the famine and cholera in India sixteen years ago, can easily form such a conception.

examined, the more shall we be convinced that we must look, not to grand cosmical conditions, not to earthquakes, comets, or mysterious waves of an unseen and poisonous air; not to recondite epidemic constitutions, but to simple, familiar and household conditions, to explain the spread and fatality of the mediæval plagues." And so it is true for this great country, that disease will continue to claim its victims in excess until, by slow degrees, the narrow streets are cleaned and widened and the wretchedly-built houses replaced by others of suitable form and construction.

Attempts have been made in the large towns to remedy this state of matters as far as may be, but it is an evil of such magnitude as to make the task seem almost hopeless. Poverty, that bar to sanitary progress in India, is here the chief obstruction, but a great deal can be done by improving the *design* of even very small houses without much increasing the cost. It is to be hoped that natives of this country, graduates in engineering and sanitary science, will take up the question energetically and design dwellings which, whilst conforming to local taste and customs, will be constructed as far as possible in accordance with the canons of hygiene.

What then are the requisite conditions for a healthy habitation? They are chiefly these, as defined by Parkes :—

1. *A site dry and not malarious,* and an aspect which gives *light and cheerfulness.*
2. *A pure supply and proper removal of water;* by means of which perfect cleanliness of all parts of the house can be insured.
3. *A system of immediate and perfect sewage removal,* which renders it impossible that the air or water shall be contaminated from excreta.
4. *A system of ventilation which carries off all respiratory impurities.*
5. A condition of house construction which insures *perfect dryness of the foundations, walls and roof.*

Now, let the reader think for a minute how many of the houses he is acquainted with fulfil these conditions: the answer will probably be—'not one'!* Yet there is nothing out of the way in these five postulates, save perhaps the demand for a non-malarial site. Even in this case, a little care in choosing and preparing the original site of any place would obviate this objection almost, if not quite entirely.

Not only, then, is it very exceptional to find a dwelling house or group of houses fulfilling all these conditions; it is the general rule to find that every one of them is violated. An undrained, malarious site; a water supply of extreme impurity; no proper system for removal of excreta and none for removal of impure water; ventilation practically *nil;* unsuitable materials used in the building and a thoroughly defective method of construction,—such are the almost invariable conditions of Indian houses. Is it any wonder that the people die by thousands of fever, cholera, phthisis, etc., and are at best a poorly developed race lamentably deficient in stamina? It is not denied that many other of the essentials of healthy living are wanting, such as good food, temperance in all things, regulated physical exercise and proper clothing, all of which will be discussed under Personal Hygiene,† but the fact remains that imperfect and insanitary dwellings are a powerful factor in aiding the virulence and spread of disease.‡

* Let him remember also that an 'unhealthy dwelling' is invariably an *expensive one* and a bad bargain. People generally realise this when it is too late; when the favourite child has died of diphtheria or the chief bread-winner been carried off by cholera or enteric fever, or when half the family begin to suffer from malarial asthma.

† *v.* Part II, The Hygiene of the Individual.

‡ *E.g.*, Dr. Ballard, reporting recently to the Local Government Board in England, upon the annual mortality from diarrhœa, points out, among the more important conditions influencing diarrhœal mortality, that aggregation of population favours, and dispersion over area disfavours, diarrhœa; that density of buildings (whether dwelling-houses or other) upon area promotes diarrhœal mortality; and that restriction of and impediments to the free circulation of air, both about and within dwellings, promote diarrhœal mortality. Quoted by S. and M., p. 657. In all eastern towns which, in the close aggregation of their houses and the consequent narrowness and tortuosity of their streets, resemble the towns of Europe in the

In considering this subject attention must be paid to the different classes of buildings inhabited by human beings in this country.* They may be thus classified :—1. Houses, (*a*) of the Wealthy, (*b*) of the Poor, (*c*) of the Nomadic tribes or castes, and (*d*) Camp life in Tents : 2. Hospitals, (*a*) for General or Special diseases, (*b*) for Infectious diseases : 3. Jails : 4. Barracks : 5. Schools : 6. Shops and Offices, Courts, etc.† The two latter classes, 5 and 6, are not, strictly speaking, dwellings, but as a large number of human beings pass a considerable portion of their lives in these buildings they require to be noticed.

HOUSES—OF THE WEALTHY.

By this heading is not meant that all who live in large houses are necessarily wealthy and *vice versâ,* for it may be that owing to special circumstances a comparatively poor person may live in a large house, whilst, contrariwise, nothing is commoner in this country than for a man who is really wealthy and could easily afford to live in a proper house, to prefer instead a tumble-down hovel in a back lane off a bazaar, so that he may save a few more rupees ere he quits this earthly scene—and leaves them all behind him! The houses referred to here are the detached bungalows occupied by well-to-do Europeans and Natives and the larger houses in the streets of the chief towns.‡

By far the greater number of these are built either as a pure speculation or else by people who have prospered in life and wish to settle down, in which latter case the work

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middle ages, the rapid and fatal spread of epidemics is very largely due to the concentration of the impurities on a very small area.

* The consideration of the *collections* of huts or houses which go to form villages and towns, in their relation to external ventilation and the general health of the inhabitants will be found under Part IV, Practical Sanitation.

† There are many other classes of buildings such as Hotels and Hostelries, Churches, Public Halls, etc., which require equal care in construction and subsequent supervision, but space forbids mention of them.

‡ The scope of this work does not permit nor require reference to the palaces of Rajahs and other Nobles nor to the official residences in the various presidencies.

is almost invariably entrusted to an ignorant contractor. In some cases the houses have been built under official supervision and in these the work is generally of a better nature. In every way, save in point of size of the rooms, Europeans in India are worse housed than those of a corresponding class in Great Britain and this is partly due to the fact that, with rare exceptions, their Indian dwellings are only temporarily occupied by any one family, and partly to the fact that the same class of work and material is not procurable here without disproportionate expense. The large bungalows standing in several acres of ground, seen typically near Madras and Calcutta, which were formerly the usual dwellings of Europeans, offer, no doubt, many advantages of comparative distance from dirty bazaars and *parcherries* or *busties,* quietness, fresh air, etc., but the day when the tenants could well afford to keep them clean and in repair, and pay a proper rent for their occupation, has gone by. Hence is commonly seen the insanitary and disagreeable sight of a half-empty, ruinous bungalow in a dirty, unkept compound, through which latter is a 'right of way' in any direction and, apparently, free grazing for the cattle of all and sundry. There are few pleasanter dwellings to look upon than a clean, handsome bungalow in a well-wooded compound, but such is daily becoming a rarer sight.

1. Referring once more to the requirements of a healthy dwelling, as instanced at the commencement of this chapter, the first necessity is a dry and non-malarious Site and a good Exposure. These have already been discussed.* The site of a large bungalow is frequently the best available in any particular place and, if malarious, it is generally owing to the existence of swampy, undrained ground in the neighbourhood, coupled, it may be, with defective foundations of the house itself. These latter will be alluded to afterwards.†

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* *v.* Chap. III, p. 111, *et seq.*, and p. 126, *et seq.* Exposure will again be referred to under 'ventilation' of houses, hospitals, etc., in this chapter.
† *v.* 'Foundations', pp. 230-1.

2. The arrangements for Water Supply and the removal of dirty water have already been described,* but a few points remain to be noticed. Except in bungalows situated in the largest towns, the water supply is almost invariably from a well in the compound. This well is frequently situated in a bad position and not seldom is merely a *shallow* well, although its actual depth is considerable. When the water level is high the pressure within the well may keep back the surface soakage to a large extent, but during dry weather any impure water which dribbles through the cracks and fissures in the upper layers of the soil meets with no resistance and may often be seen oozing through the sides of the well and dropping into the water below.† In large towns with a proper water supply there should be a stand-pipe available in every compound for watering the garden, flushing drains, etc. If the natural pressure or 'head' is too small to deliver the water to the upper stories of the house, the municipality should certainly make use of Shone's ejectors as before described, erecting a small compressed air station if necessary.‡ Water should be laid on to the pantry, kitchens, stables, etc., and the waterman abolished. Otherwise, cleanliness of the house is almost impossible.

For the removal of Dirty Water, in most cases, there is practically no provision whatever. When a house is first constructed a few miserable channels, lined with country bricks and chunam, are built, chiefly with the intention of carrying off rain water. In a short time these become completely choked or destroyed, with the result that the whole of the dirty water from the house and the rain water from the roof sink into the ground, which is

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* *v.* Chaps. II and IV.

† When the writer was acting as Chemical Examiner in Madras, a gentleman sent a sample of water from the well in his compound and wished to know if it was fit for drinking. Analysis showed that it was practically sewage!

‡ *i.e.*, in a place where the hydro-pneumatic system for the removal of excreta is not already in use. All that is required is two small engines and two sets of air pumps, with a small supply pipe for conveying the compressed air to the ejectors.

thus saturated with moisture and filth.* In some cases hollow, and usually porous receptacles, of limited capacity, are placed at the foot of the pipes from the bath-rooms and pantry. These receptacles constantly overflow and, under any circumstance, are only emptied at the leisurely convenience of the sweeper and after the liquid has been exposed for many hours to a tropical temperature. The proper remedies for such a state of things cannot be applied unless the landlord is forced by the authorities to *make and keep in order* suitable drains, and the tenants of the houses take a personal pride in seeing that all is clean and sweet. All sullage water could be quite easily and harmlessly disposed of by leading it to one or more points in the garden for use in irrigation, the drains being flushed daily, if possible, with a few gallons of clean water and occasionally scraped by the sweeper.† The arrangements for the removal of rain and house water will be alluded to again under construction of houses.

3. The third condition, immediate and perfect Sewage Removal, has been fully considered in the last chapter and in the preceding paragraph. As regards the Removal of Excreta proper, the very simple method adopted in this country has been alluded to already.‡ It is fairly satisfactory, when properly carried out, but might be considerably improved. In the first place the practice of using the bath-room, which is in immediate connection with the bed-room, as a privy is a mistake. In each house there should be two partially-detached rooms§ for exclusive use as privies, one for males and one for females, the bath-rooms

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* *v.* Chapter IV, p. 197, and footnote.

† *Ibid.* At first sight it appears as if the European tenants of these houses coming, as they do, from the most hygienic country in the world, are largely to blame for such a state of matters. And so they are to a considerable extent, in most cases, but it is to be remembered that they are constantly changing their residence and servants, and it is very disheartening to have to keep on complaining to every landlord and trying to train fresh servants. The first essential is to *compel* landlords to make proper provision for the removal of all rain and dirty water.

‡ *v.* p. 136.

§ With thorough cross ventilation between them and the house.

being used exclusively for purposes of ablution. By a slight re-arrangement this could easily be managed in the design of a new house without adding to the expense. A little water, containing, if desired, a few drops of a deoderant such as sanitas fluid, should be placed in the pan before use, or else a box containing dry earth and a scoop should be at hand and the motion covered with dry earth* immediately. For the reception of the excreta, both liquid and solid, the sweeper should be supplied with a water-tight, metal receptacle, tarred inside and out. This should be kept in a place easy of access by the municipal scavengers, but invisible to the ordinary passer-by.†

4. Coming next to the subject of Ventilation, which has already been dealt with,‡ there are still some practical points to be noted. It is not too much to say that the ordinary Indian house is built without any regard whatever for ventilation, the only idea being to obtain a certain degree of shadiness and coolness. Unless the greatest care is taken in designing the house, these two conditions, *viz.*, good ventilation and coolness, will not be obtained, the result being a cool house in which the air constantly stagnates, or *vice versâ*. When a house is completely shut up during the day in hot weather, there must be some special means of ventilation in action if the air is to be kept pure.§ In a one-storied bungalow, which is the usual type throughout India, the area covered by the building is very large, and though the vertical height of the rooms in the centre of the building may be considerable, the eaves project all round the outer edge of the verandahs to within a few feet from the ground. In addition, there are commonly no vertical openings through the roof such as are naturally

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* Note, once more, that sand is quite useless; on the small scale, suitable earth can always be obtained and prepared for use.

† The ordinary practice of having an old leaky kerosine tin with no handle, placed in as conspicuous a place as possible, is neither sanitary nor decent.

‡ *v.* Chapter I.

§ Under any condition pure air is necessary, but it is especially so in the case of people who are obliged to pass the greater part of the day in partial darkness, for months together.

made for chimneys in colder climates. The result is that when the doors and windows are closed the house is like a box with the lid shut down and the ventilation is almost *nil.* If it were not that the fittings in Indian houses are invariably defective owing to bad material and workmanship, and warping from the heat and damp, the air within the house would soon become unbreathable.

In the heat of the sun there exists for utilisation a source of ventilation almost, if not quite as powerful as a good fire. By the use of shafts of wood, brick, or iron, painted black and with a curve, if necessary, to prevent the direct passage of the sun's rays, placed in the highest point of the roof and projecting upwards several feet, a most efficient outlet can be made.* To compensate for the out-going air efficient inlets must be provided. They are best placed over the doors or windows as a general rule, and may be simple openings covered with wire-netting or gauze, or may be more elaborate and artistic. It is very desirable that there should be some means of cooling and filtering the in-coming air which is nearly always hot and dusty. This might be managed by making the inlet in the form of a metal box or short metal tube of zinc or copper, somewhat after the nature of a Tobin's tube, but projecting outwards for two or three feet, and covered with felt or cloth kept constantly moist by a simple automatic apparatus, such as a water container perforated with holes through which wicks are passed, and placed over the tube. The outer end of the tube should be covered with metal gauze to prevent the entrance of birds, etc., and near the inner opening a removable screen of Jute cloth could be placed. Such a plan would only work well in a comparatively dry atmosphere, where the metal inlet was kept well in the shade but exposed freely to the movements

* In connection with this subject Mr. Wallace made experiments with a bit of thin sheet iron, 22 inches square and 10 feet high, left black and unpainted. The velocity of the current through the tube was found to be 133 2 ft. per minute, which multiplied by the area of the tube (3·36 sq. ft.) gave 447 cub. ft. per minute, or 26,853 cub. ft. per hour. For further details, *v.* Wallace, *op. cit.*, p. 194.

of the air.* When the air is warm and moist, and at the same time very still, it is by no means easy to ventilate a house satisfactorily. Reliance must be placed on simple openings which will act as inlets or outlets on occasion, and on simple perflation by opening doors and windows.† The whole subject of the ventilation of Indian houses in the plains needs to be studied scientifically and carefully, and practical use made of the knowledge thus obtained. On the hills there should be no difficulty in securing sufficient ventilation, but there the houses are, if anything, worse off than those in the plains in this respect.‡ Many of the rooms are very small and absolutely unprovided with means of ventilation, save a chimney. Sometimes even that is wanting. Such carelessness is quite inexcusable, more especially when it is remembered how essential fresh air is to the worn-out or invalid toilers from the great heat of the plains.§

With regard to the larger houses situated in the streets of Calcutta, Bombay and other towns, there are many objections as regards site, drainage, and especially ventilation. The external ventilation is so bad that it is impossible to get pure air in the houses, and the general surroundings are in every way defective, not the least drawback being the constant noise from the street traffic,

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* The only doubtful point is whether the length of the tube would not have to be considerably greater. It might be bent or in the form of a short spiral, though in that case there would be considerable friction. *v.* Suggestion by Wallace, *op. cit.*, p. 191.

† "The semi-hexagonal layer of the Allahabad system (*v.* note, p. 236) serves the purpose of ventilation. In flat roofs circular openings are generally made in the terrace and surmounted by a cap slightly raised above the roof surface, the air escaping through the joints between the flat tiles into the channel formed by the hexagonal."

‡ Exception must be made of some houses built under the personal superintendence of retired medical officers and others, and of some official residences.

§ All houses on the hills, and elsewhere, should be periodically inspected, and compliance with at least the rudiments of sanitation insisted upon. No railway can be opened till every part of the permanent way, rolling stock, etc., has been inspected. It is quite as necessary that the same precautions should be taken for the health of people powerless to defend themselves. This subject will be referred to later.

etc.* It is possible that in time to come Anglo-Indians may be obliged to live in tenement houses situated in or quite near to the town, but if this is so there must needs be great improvement in many directions.

Regarding the use of punkahs, to which reference has already been made,† Mr. Wallace, C. E., has made interesting experiments‡ as to the most suitable form for producing a downward current. "A punkah curtain is a ship's sail reversed. It is drawn through the air in order to produce a current in a desired direction. It must curve or 'belly' as the sail does, in order to facilitate the movement of the air, and the rod§ at the lower edge must be of such a weight as to produce a curve on the curtain like that of the blade of a revolving fan. The curtain should be perfectly plain, and of the thinnest possible material, such as muslin or fine silk, and the suspending cord should never exceed ¼ of an inch in thickness. Lightness in appearance should always be the object of the designer. Round bar iron, 1¼-inches in diameter, covered with leather or leather cloth, makes a very effective swing-bar with

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* *E.g.*, the noise from the steam whistles of the Jute and other mills near the suburb of Cossipore, at Calcutta, is most distracting, especially to those who sleep lightly or are sick. There should be only one steam whistle at a central spot, and this should only be blown at fixed hours.

† *v.* note, p. 30.

‡ "Twenty-five pulls per minute represent the economical speed of working of an average coolie, so all suspended punkahs should work at this rate, however high the roof may be.—The simplest way of finding the length of the suspending cords is to hang the punkah temporarily with cords going over the hooks and fixed within reach, or held by hand. The length may then be altered till the right speed is found. Ceilings up to 16 feet high will give a fair approximate length to punkahs, which must be hung 6 feet clear off the floor. Twenty-five pulls of three feet will give a speed of 150 ft. per minute to the punkah bar. The pull should be in a downward and not in a horizontal direction, and to make the work as easy as possible, the swing-bar should be made heavy enough to lift the arm of the puller during the return movement.—If the roof of a room be too high for the proper swinging of punkahs, they may be hung in the ordinary manner, and the centre of suspension may afterwards be altered by attaching a light bar of wood across the suspension cords, horizontally, but at such a height from the swing-bar as to give the right length for speed of movement. The bar is next fixed by thin wires to opposite ends of the room so that it cannot swing; it thus becomes the true centre of suspension of the punkah."—Wallace, *op. cit.*, pp. 185, 187.

§ A light piece of wood.

polished hard wood ends. When hung with 3-inch iron rings on the suspending hooks, the rubbing is transformed into a rolling motion and the punkah is noiseless.

5. The last condition for a healthy dwelling, demanded by Parkes, is Proper Construction, insuring perfect dryness of the foundations, walls and roof. In this country must be added another condition, *viz.*, construction such as will be amply sufficient to protect from the direct heat of the sun's rays and to insure reasonable coolness of the house at all hours.

Under various local acts, such as the Madras Municipal Act and the Madras District Municipalities Act, notice has to be given of any new building or restoration, with plan of foundation and of ground floor, statement of means of ventilation, drainage and privies, and such further particulars as may be required under bye-laws. So far as can be seen the supervision exercised on the strength of the above clause is by no means thorough and houses continue to be erected on the old plan with nearly every possible fault in their construction. The greater number of bungalows occupied by Europeans have been built for some time* and as a consequence it is not possible to do much in the way of improving the original design. Of late years there has been a considerable improvement in buildings erected under official supervision and a higher class of work insisted upon, so it is to be hoped that in time to come a corresponding betterment in the houses in which ordinary human beings are compelled to reside may occur.

In the construction of a house the following parts require separate consideration—(*a*) The Foundation; (*b*) the Walls; (*c*) the Floors; (*d*) the Roof and Ceilings; (*e*) the Out-houses, including the Kitchen.

Foundations.—Before starting the actual erection of any building careful attention must be paid to the choice of a

* *E.g.*, in Madras the larger bungalows were mostly built from 30—40 years ago or longer and are nearly all in a state of impending dissolution.

site, if possible, and also to the nature of the soil on which the building is to be erected. This latter point is chiefly a question for engineers, but if there is any reason to suspect that it is 'made soil'* or that the ground is in any way unsuitable from a hygienic point of view it should be carefully examined by a sanitary expert. The object of carrying the foundation of a building below the surface of the ground is to guard against the soil under the bottom of the masonry being softened and exposed or undermined by rain, etc.; also, where the top soil is easily compressible, or loose, to obtain a firm footing. In soft ground the foundation is made very broad at the bottom or better still, a good, continuous bed of concrete or asphalte is very carefully laid down.* In addition, to prevent damp from rising in the walls by capillary attraction,† a 'damp proof course' should be inserted. This consists of a continuous layer or course of impervious material such as slate, glazed earthenware, vitrified bricks, or hydraulic cement, etc., laid horizontally for the entire thickness of each wall, above the point where the wall leaves the earth, but below the level of the floor. Efficient ventilation, with resulting dryness of the floors, may be obtained by leaving a clear space between the foundation and the floor, with occasional openings to the outer air, but it must be very carefully done so as to exclude all chance of the entrance of insects or vermin. A still better plan is to elevate the house on pillars or arches, care being taken to keep the spaces thus left perfectly clean and dry.‡

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* In preparing the bed of the foundation careful search must be made for white ants, and if found, they must be completely destroyed by tracing down the burrows, till the queen ant is secured and killed. For further details on this and subsequent sections. *v.* Roorkee Treatise on Civil Engineering, sections II, III and VI.—Jones' Manual, etc.

† The amount of moisture that can be absorbed by the walls of a building is very great. An ordinary brick will hold about 16 ounces of water, and during monsoon weather the walls of mud huts are like sponges saturated with water.

‡ In Burmah and other countries it is customary to raise the houses on poles or on arches, but the benefits thus derivable are largely neutralised by the ground surface being allowed to remain constantly wet and filthy; in fact, it is made the receptacle for dirty water, scraps of food, etc.

Walls.—Walls in India are mostly built of brick. The bricks are generally the common 'country' sort, which are made of poor material, sun-dried or dried in rude kilns, and most erratic in shape. The result of this latter failing is that it is impossible to get proper 'bond'* in the wall, which thereupon begins to crack in a short time and allows the passage of moisture, insects, etc. Where good chunam mortar or cement are used with well-baked ('P. W. D.' or 'Government') bricks, properly laid, a thoroughly suitable wall can be constructed of the thickness of a brick and a half.† Various other materials are used for the houses of the poor, temporary structures, etc., which will be described afterwards. Double walls, with a ventilated space between, are very good and keep a house dry and cool, but the constant presence of squirrels, rats, etc., makes it difficult to prevent a nuisance arising from this cause.

The outsides of the walls in nearly all houses are plastered and whitewashed.‡ The former is done merely to hide the *kucha* brickwork, but the whitewashing has undoubtedly the effect of preventing the absorption of a large amount of heat. It is becoming the custom in the case of officially built houses, etc., where good bricks and neat work are employed, to leave the outside walls with the bricks exposed, in other words of a red colour. It certainly looks well and is refreshing to the eye, but the buildings are

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* Bonding is the arrangement of the bricks in respect to one another, so that no joint in any course shall be in the same place with any other joint in the course immediately above or below it; the object being to preserve a transverse and longitudinal tie between every portion of a structure, so that its stability should be practically independent of the mortar.—Jones, *op. cit.*, p. 135.

† "A brick and-a-half wall of *pucka* masonry will carry almost anything. As a rule, there is much unnecessary masonry in Indian houses," and this means waste of money that might be much more usefully expended in proper surface drains, etc.

‡ The plaster used in India is really finely-ground mortar being made of chunam and river sand or chunam and white sand in varying proportions. Sea sand must never be used, on account of the hygroscopic salts that it contains. Whitewash is made by adding slaked lime to a solution of gum, glue or rice-water. Sometimes blue or yellow washes are used, but they are not so useful in preventing the absorption of heat. Dark blue is especially bad.

proportionately hotter, as anyone who has to live in them soon finds out.*

The inner sides of the walls are generally plastered and whitewashed also; this being required on account of the rough nature of the work. Where the wall is well made of good bricks, properly 'pointed,' this is quite unnecessary, the inner surface being simply painted with oil paint and therefore washable. As to whether the walls should be built of or covered with some impermeable material, there is a difference of opinion. Some consider that the porosity of the wall is a good thing as being an extra source of ventilation, but this is an error and a tacit acknowledgment of failure to ventilate a house by the proper means. What is really wanted is a smooth, washable and non-absorptive surface, which is in addition impermeable, so that it can be cleaned periodically and will prevent the entrance of heated air or moisture from without. For this purpose nothing is better than the beautiful plaster of Madras with its polished surface resembling white marble.† But the process, if done properly, is a lengthy and costly one‡ and repair after injury is difficult. Encaustic tiling or cement are excellent for kitchens, bath-rooms, etc., and will probably be used largely some day. At present the best available method for general use is good hard plaster covered with oil paint. The papering of inner walls, almost universal in England, is comparatively uncommon in India and is not to be recommended, save possibly for reception and dining rooms. Care must be taken that arsenic is not mixed with the 'size' used for making the paper stick to the wall.§

* The tendency to make Indian houses conform to European styles of architecture is certainly a grave mistake. Given materials and workmanship of European goodness, elegant and hygienically suitable buildings, adapted from various oriental patterns, should be designed and built as standing examples for the native builder to copy.

† *E.g.*, St. George's Cathedral, Madras, where the plaster, about sixty years old, is smooth and beautiful still.

‡ *v.* Jones, *op. cit.*, p. 128, *et seq.*

§ It is commonly added in large quantity by the native workmen to prevent insects destroying the paper, but there are other harmless sub-

Floors.—In a cold climate like that of Great Britain the floors of houses are almost invariably made of wood, but in India the practice is neither advisable nor necessary in an ordinary house. Here the flooring may be made of a variety of materials;—bricks, stones, tiles, broken bricks and mortar (terraced floors), cement, asphalte and wood are all used. Like many other things in India, the custom of the place or district largely determines the use of any particular material. A terraced floor,—made of a layer of broken brick (or *kunkur*) and a little mortar well beaten in, followed by a layer of *súrkhí* mortar well beaten in, and finished with a layer of fine shell lime or, better still, cement,*—makes a very good floor for use in houses. The great drawback of such a floor is that it is difficult to repair; indeed the whole floor must be taken up and relaid if a good job is to be made of it. For large houses, the most suitable method of flooring would probably be to have the centre made of the best terrace work covered with cement, the margin, about two feet wide all round, being made of encaustic tiles pointed with hard cement. By such an arrangement the carpet, or other covering of the floor, need not cover the entire room, so that greater cleanliness and security from the ravages of insects are secured. Whatever flooring be adopted for the ground storey it should be air and water-tight. This is of *supreme importance* in this country.†

Upper floors are often made of wood.‡ When this is the

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stances which would doubtless do instead. Of course, no paper containing arsenic in the colouring matter should ever be used, as such a practice is very liable to cause chronic ill-health from arsenical poisoning in some individuals.

* Only good mortar must be used and the beating must be very carefully done. The surface layer of lime or cement must not be too thin, as is frequently the case, or it will certainly crack and permit the passage of moisture, dust and insects.

† There is little doubt that with pure drinking water, suitable clothing and a house with impermeable floors and walls, good health can be maintained by any one for a long period in a malarious place, whilst others, under less favourable conditions, suffer from repeated attacks of malaria. *v.* chap. III, p. 128.

‡ Various devices for rendering a wooden floor impermeable and non-absorptive of dirt and moisture have been invented. One of the simplest

case the joists and planks of the floor should form the ceiling of the room below so that neither dirt nor vermin can remain concealed. In England the space between the plastered ceiling and the floor above is usually filled with 'pugging' to deaden sound; it is not a good practice at any time, but is absolutely inadmissible in this country.

It is essential that precautions be taken during the construction of a house or other building to protect it from the ravages of white ants. For this purpose yellow arsenic or orpiment (*hartál*) is most generally used, but great care is required if this is done. Having ascertained that the foundation area is free from white ant burrows,* arsenic is mixed with the concrete, mortar and plaster used in the foundation, floors and walls to a height of four feet, but *never in any surface coat* so as to be exposed to attrition or rubbing. The mixing and application should be done under competent supervision.

Roofs.—The roofs of Indian houses are divisible into two classes, flat or *terraced* roofs and sloping or *pent* roofs.

Terrace roofs should have just slope enough (not less than 1″ in 10′) to allow rain water to flow off their surface. They are often very badly made and after a little time begin to crack and even gape. In many native houses they are much used as a place of resort in the evening and thus subjected to extra wear and tear. The consequence is that they leak† during rainy weather and render the house and its contents, such as beds, clothes, almirahs, etc., damp. Their construction being much the same as ter-

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and best plans consists in melting solid paraffin (*paraffinum durum*, B. P.), pouring it on the floor and ironing it in with a box-iron. The excess of paraffin is scraped off and the floor brushed with a hard brush: a little paraffin in turpentine is then put on, and the flooring is good for years. Longstaff, quoted by Parkes-Notter, p. 226. This would probably do excellently for teakwood floors. Other plans, suitable chiefly for softer woods, are given in S. and M., p. 777, *v.* also San. Record for 1893.

* *v.* note, p. 231.

† For compositions used to fill the cracks. *v.* Jones, *op. cit.*, p. 144. When an old roof is repaired by covering with asphalte it should be painted white, for coolness. *v. post.* p. 259.

raced floors,* the same care in laying the courses is necessary, and only well-seasoned timber should be used for the roofing.†

Pent roofs have very various coverings, such as terrace work, tiles, slates, thatch, corrugated iron, etc. Tiled roofs are coming more and more into fashion owing to improvements made on the common pot tile of native brick works. By far the best are the Mangalore and Allahabad tiles which are made of first class material and accurately to size. The details of construction of these tiled roofs are too elaborate to be described in this work.‡ In the Punjâb and some hill stations slates or stone flags are used and if the slates are of equal dimensions and not laid too sparsely they make a good roof. On the hills, wood planking, tarred over, and shingles, *i.e.*, square pieces of split wood, are also used for roofing. They are cool enough, but such roofs are certain to leak ultimately, besides remaining damp for a long time during wet weather.

Thatched roofs, consisting of long wiry grass laid in bundles on a bamboo frame work, and from six to twelve inches in depth, are very cool and wonderfully dry. They are largely used for bungalows in certain parts of India where the heat is very intense. Their chief disadvantages are the liability to take fire and the number of squirrels, rats and other animals which they harbour. It is a quite unsuitable material for most buildings, especially hospitals, other than very temporary ones. Corrugated or galvanised iron, zinc and lead sheeting, are all used as roof coverings, but especially the former. For houses in the Indian hill stations the favourite form of roof for excluding the frequent

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* In the same way as for floors, instead of a lower foundation of bricks, tiles or stone flags may be used. "Three layers of tiles laid to break joint, the upper layer being covered with a thin coat of plaster, well polished and oiled, forms a very durable flat roof, and possesses the advantage of being lighter than a terraced roof, and in any case it is the upper surface that the water-tightness of the roof depends upon."—Roorkhee Treatise.

† Used here in its technical sense, *viz.*, the joists, rafters, etc., upon which the roof covering is laid.

‡ *v.* For description of the former, Jones' Manual, for the latter, the Roorkhee Manual.

and heavy rainfall is a roofing or framework of wood covered with corrugated iron, the latter in its turn having a covering of Mangalore or other tiles. Without the tile covering, the iron roof is noisy during rain and hot.

Ceilings.—In a flat-roofed house of one storey only, the roof timbers are generally left uncovered internally except for a coat of paint, or stain and varnish, so that any injury done by insects can be at once detected. On the hills the same thing can be done with the pitched roofs of corrugated iron, but if these latter are used on the plains it is necessary for coolness' sake to lay a wooden ceiling underneath. In houses of more than one storey the ceilings of the ground-floor rooms are best made by simply leaving the joists and flooring of the room above exposed and painted any desired colour. There should be free ventilation and means of inspection round the ends of all wooden beams,* but the openings must be carefully closed with metal gauze to prevent the passage of birds and rats.

In former days a very favourite form of ceiling for a pent roof was that made by coarse canvas (ceiling-cloth) stretched flat on a frame beneath the roof and timbers and painted white. It looks well when new and bears a distant resemblance to an ordinary plastered ceiling, as used in England, but it has many disadvantages and is generally a quite unessential addition.

Rain pipes.—It is very important that a house should be provided with efficient means of getting rid of rain water as soon as it falls, and by getting rid of it is meant its complete removal to a distance. This is easily managed either with a flat or pent roof by having proper rain pipes fixed and *kept in repair.* With a pent roof there should be gutters placed all round the lower edge of the roof and verandahs to catch the rain, with openings into down-take pipes at intervals, these latter being bent outwards at the

* On account of the initial expense and liability to destruction of wood, Iron girders, trusses, etc., are coming more and more into use in Indian buildings.

foot and discharging into the surface drains running round the house.* Where the roof is flat the best plan is to have the water discharged through short spouts carried well out from the wall, the area on which the water falls being cemented and grooved so that the water flows away into the surface drains. It should be an axiom that *no water of any kind, clean or dirty, should be permitted to fall on and soak into the ground immediately surrounding the foundations of a house.*

Out houses and Compound.—Another point in which most Indian houses fall far short of sanitary requirements is the situation and condition of the out houses and stables, and the state of the compound. As a general rule, the kitchen, servants' godowns, stables and coach house, with other buildings often in addition, are all crowded together in admired disorder. In nearly all the older bungalows these 'offices' are in a semi-ruinous state and unspeakably filthy, the neighbouring subsoil being saturated with the organic pollution of years. Add to that a dirty hole or tank, sometimes full, sometimes empty, *always* used for purposes of ablution, bodily and otherwise, by the servants, a tumble down and dirty servants latrine or a tangled mass of undergrowth which serves this latter purpose, and one has a picture, by no means overdrawn, of fifteen out of twenty compounds.† Hence arise those seemingly mysterious cases of sudden disease,—cholera, typhoid fever, etc.—

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* The down-take pipe should be kept well away from the wall by supports, and both this and the gutters and spouts examined and cleaned periodically.

† As stated before (*v.* note, p. 225) the responsibility for such a state of things must generally be divided between the landlord and tenant. The former, however, has undoubtedly the advantage in most large towns and has kept on raising the rent to suit each fresh valuation or taxation by the municipality, while the tenant, powerless to pick and choose his residence, owing to the paucity of houses, has perforce to pay an enormous rent out of a salary worth just half its nominal value. There is no doubt, from information received from thoroughly trustworthy sources, that in former days when officials were more settled and received suitable remuneration, the ordinary bungalow compounds were much better kept in every way. In some *mofussil* stations, originally the sites of cantonments, the above conditions are reversed and it is the tenant's fault if the compound remains in a filthy condition.

which attack and carry off child or parent and are put down to the unhealthy climate!

In a new house, then, the kitchen, godowns and stables should be kept separate, and the godowns limited in number as much as possible. Tanks are quite unnecessary when there is a pipe water supply: if wells are made they should be carefully constructed* and their use ordinarily confined to garden purposes. Water should be laid on to all the buildings, and properly cemented places, leading to the surface drains, constructed for the washing of servants, carriages, etc. There should be a dry earth latrine for the use of the servants and the master of the house should feel it to be his *duty* to inspect the same periodically or else, if he feels unequal to the task, to depute the same to responsible authority.

Kitchens.—Indian kitchens, as being the place where the food which we eat is prepared, deserve careful notice. Yet what good is it possible to say of them? The following extracts from the pen of a well-known reformer† in this matter may serve to bring the picture more vividly than otherwise possible before the thoughtful reader. "Remembering as we all can so well the cheerful aspect of the English kitchen, its trimness, its comfort, and its cleanliness, how comes it to pass that in India we continue year after year to be fully aware that the chamber set apart for the preparation of our food is, in ninety-nine cases out of a hundred, the foulest in our premises—and are not ashamed? * * * Why, in short, in the one country are we scrupulously careful that our food shall be clean, and in the other at all times willing, apparently, to eat dirt?"

"Over and over again have revolting facts been discovered in connection with the habits and customs of the cook room. But instead of striking at the root of the evil,

* *v.* pp. 54-5.

† Culinary Jottings for Madras, Wyvern, 5th ed., p. 496, *et seq.*, where the original article should be read by all interested.

and taking vigorous action to inaugurate reform, we are callous enough not only to tolerate barbarisms, but even to speak of the most abominable practice as jests ! Though cognizant, that is to say, of the ingenious nastiness of our cooks, we shrug our shoulders, close our eyes, and ask no questions, accepting with resignation a state of things which we consider to be as inevitable as it is disgusting."

"But is it inevitable ? Think first of all of the distances which as a rule separate our kitchens from our houses, and the fact that the room is part and parcel of a block of godowns—not unfrequently within easy access of the stables. Setting aside other considerations for a moment, do we not at once perceive here two grave evils : in the first place that proper supervision of the kitchen is almost out of the question ; and, in the second, that promiscuous gatherings of outsiders,—the friends, relations and *children* (a fruitful source of dirtiness) of our servants—can take place in it undetected ? Again, the room is generally constructed with as little ventilation and light as possible, its position with regard to the sun is never thought of, and arrangements for its proper drainage are rare. As there is no scullery, or place for washing up, etc., the ground in the immediate vicinity of the kitchen receives the foul liquid (as well as all refuse matter) which is carelessly thrown out upon it. The consequence is that hard by many a cook room, there is a noisome cesspool containing an inky looking fluid, the exhalations from which can scarcely improve the more delicate articles of food which are sent from the house for preparation."* The writer then passes on to describe the condition of the interior of the kitchen and the miserable fittings in connection therewith, and shows that it is impossible to expect the cook, amidst such degrading surroundings, to be clean in his habits or person. Most reasonable suggestions are made as to the situation, fitting up and general arrangement of the kitchen as it should be, and attention drawn to the fact that though

* There are much more *serious* objections to such a practice than this.

considerable opposition may be met with in the first case, a *good* cook will speedily appreciate light, airy and clean quarters, and that reform from without will sooner or later be followed by reform from within.

HOUSES OF THE POORER CLASSES.

That this is a subject of vast importance, no one who has an intimate knowledge of the conditions under which the millions of Indian poor live, will attempt to deny. That these conditions are not in themselves so absolutely degrading, so completely brutalising as those to which the poor of London, Paris and other great European cities are subject, is more or less certain, for even the poorest classes, the pariah and the ryot, are merely ignorant and uncivilised and have not had grafted upon them the unspeakable vices and misery which result from a long process of *decivilisation*. In addition, there are certain things in favour of the Indian poor, *e.g.*, the regular family life—as opposed to the swinish herding of the sexes in the East end of London—and the tropical climate, which is not so directly inimical to life as an English winter.* But even so, the fact remains that the dwellings of the poorer classes are of the rudest and most imperfect description and their surroundings worse.

In towns the buildings are of better construction, but any advantage derived in this way is more than negatived by

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* In connection with this subject, the writer, in a course of lectures on the Principles of Hygiene delivered in Madras at the request of the Council of the Victoria Technical Institute, said,—"To the rich, who are able to live comfortably in special quarters and to leave them when they like, the great city seems a delightful place and they would not change for anything. But to the poor man, who has to pass one half of his life amidst the smoke and dust of furnaces, the roar and rattle of machinery, and the other half amidst that appallingly depressing scene, row upon row of small streets and slums; whilst the seasons come and go unheeded, save that it is summer, for it rains, and winter, for it is bitterly cold; to the poor man, I say, the city appears in all its hideous reality, and he curses the fate that placed him there."

"The average ryot in this country cannot be said to lead too pleasant an existence, but at least he does not know much better, and the hardships he undergoes, short of actual starvation in famine years, are in every way lighter than those of his fellow man in the slums of London, Liverpool or Glasgow."

the increased want of free ventilation and pure air. The ordinary poor live in small houses with brick walls and thatched, tiled, or terraced roofs. The foundations are shallow, the walls made of miserable bricks laid in mud or the poorest mortar, whilst the floor is simply made of mud plastered with cowdung. As a rule, there is a plinth, but owing to the method of construction of the lower part of the building, this is of little use so far as impermeability to ground air and moisture is concerned. The precautions to be observed with reference to selection of site, the allowing for free external and internal ventilation and provision for the removal of waste matter, are practically unknown; hence it is extremely common to meet with houses which violate directly every single condition of healthiness. Not only so, but care is taken to make matters worse by turning the walled-in space at the side or back of the house and the front verandah into stables or cowsheds. The windows, if such exist, are very small and are always barred, frequently shut.

The following extracts* from a description of the smaller native houses refer to some of these defects :—"The only ventilated openings in these habitations are small sized windows and doors, which too often admit only stagnant air loaded with all sorts of impurities, and never drive it out. In country places houses possess yards bounded by a brick or mud wall, which keeps the inside air very foul. A large number of houses in these places are very old and ricketty. Over a large part of the country there are no tiled and sloping roofs, but a flat layer of earth overtops the house and presses it down. Openings in the way of sky-lights in the roof to allow the foul air and smoke to pass out are seldom seen. In the Konkan and near the Ghauts, at the front or back of the houses there are generally to be found dense masses of vegetation—the delight of the owner. * * * Where open

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* K. V. Dhurandhur, L. M. & S. Trans. viith Internat. San. Sci. Cong., Vol. XI, p. 138.

spaces exist round about a house, they are very often surrounded by a fence of prickly pear or wild cane growing in luxuriance, and inviting or concealing filth of every kind. * * * In many cities the privies are found near the entrance of the house, and are ranged on both sides of the streets. In many big towns in Gujerat and the Deccan, a latrine can very often be seen in front of houses with a cook-room by its side, and a bed-room over it. * * * There is always a place reserved somewhere close to the hut of the poor or to the dwelling of the well-to-do, which serves as a pit in which all cattle dung, ashes and home rubbish are collected for one whole year, to be removed to the fields for purposes of manuring."

The poorest classes, including ryots and coolies of all sorts, live in still worse houses or huts made with mud walls, or wattle and mud, the floor and walls plastered with cowdung, the roof thatched with grass laid on a framework of bamboo. These houses are hot in hot weather, damp in wet weather and cold in cold weather; their site is generally the worst possible; windows are unknown and at night, if it is at all cold, every hole, including the door, is carefully closed.

But there is no need to dwell further on their deficiencies: it is more important to consider whether it is possible to improve them in any way. This is a matter of extreme difficulty, primarily, because the people are so poor, and secondarily, because they are so apathetic. Looking upon disease, as nearly all of them do, as sent by offended or evil deities, they are the last to be induced to believe that semi-ruinous dwellings saturated with moisture and filth can be the predisposing cause of numbers of the diseases which attack them. Any remedies that may be suggested or tried must be purely local in their effects and their exact nature must largely depend on the circumstances of the place with reference to situation, climate, customs, etc. Strict rules and regulations regarding the construction of any buildings used as dwellings by human beings are necessary,

but what is infinitely more important is that these rules should be faithfully adhered to, and that *any building erected in violation thereof should be peremptorily pulled down or its construction stopped till the needful changes have been made.** Individual poverty is no excuse for a permanent policy of do-nothing; for this matter—the better housing of the poor—is a national one and of pressing importance, if the death-rate is ever to be effectually and permanently lowered.

Two partial remedies are possible and have been applied to a small extent in Calcutta† and Bombay, *viz.*, the destruction of unsuitable buildings, *i.e.*, those which it is impossible to 'improve' in any way, and the erection, by means of private benevolence or municipal sanction, of model dwellings.‡ To these latter there is certain to be considerable opposition at first, as there was and is in England, but in process of time it would die away and the benefit to the community at large would be great. As a matter of fact there already exist such models in various 'lines' for police, commissariat coolies, Government peons, etc., but even these are by no means perfect nor hygieni-

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* Such rules do exist under various local acts. *v. Post.* Part V, Sanitary Legislation. Elaborate rules are not necessary; what is wanted is the *authority* to carry out simple regulations, and *systematic* periodical inspection, by trained inspectors, of all old and new buildings. It is a disgrace that in towns like Madras and Calcutta, occupied for many years by so cleanly a nation as the British, filthy tumble-down parcherries or bustees, rivalling, if not surpassing, the villages of darkest Africa, should still abound. Poverty is undoubtedly a difficulty, but is not a sufficient excuse.

† Demolition or improvement of insanitary dwellings in one direction is of little use, if the erection of similar dwellings in other directions is not prohibited. "If these places, which hardly anything short of clearance will remedy, are not to grow worse, and if other localities like them are not to spring into existence, building regulations which will effectually prevent huts and houses being built irrespective of ventilation, drainage, air-space, and means of scavengering must be enforced. * * In Calcutta, though considerable sums are being spent in endeavouring to improve unhealthy localities, equally unhealthy areas are arising." *v.* Report by Dr. Simpson, M. O. H., Calcutta, I. M. G., January 1887, quoted by McNally, *op. cit.*, p. 128.

‡ A wealthy Indian philanthropist, of whom there are many such, could find no better way of doing good to his poverty-stricken fellow subjects than by devoting a large sum of money to the erection of model dwelling houses, under trustworthy direction and supervision, in several of the larger towns.

cally commensurate with the expense incurred in building them: in addition, they are not the sort of houses suitable as dwelling places for the ordinary civil population.*

The rules to be followed in planning and building such houses are roughly outlined in the requirements of a healthy dwelling as before given, due allowance being made for the absolute necessity of *cheapness*. Be it remembered, however, that demand creates supply and that cement, tiles, iron, etc., will all become cheaper as they are more commonly used in construction. Finally, it is essential to secure the warm co-operation and example of the more enlightened of the community, and in getting this there will be no great difficulty if the sanitary advisers and well-wishers are in earnest sympathy with those they seek to benefit.

For the repair and maintenance in a state of comparative cleanliness of the ordinary houses of the natives of this country, the following twelve simple rules should be adhered to. (1) The use of cowdung as a covering for the floor and walls should be given up; it is *a dirty habit and an unhealthy one*, for cowdung attracts excess of moisture and forms a *nidus* for microbes. (2) Mud floors should have *the surface dug up and removed every few months*, a layer of fresh mud, to replace the mud taken away being laid on and beaten in during dry weather. (3) Mud walls should be left in their *natural condition internally*, or *whitewashed* every four months. (4) Every room should have either *two windows about 2 ft. square opposite each other* or else *one window 3 ft. square opposite the door*. Windows *must open to the outer air*.† (5) In the cook room there should be some sort of vertical opening or chimney in the roof to allow of the *ready escape of smoke*. (6) Dirty water and food refuse should on no account be thrown away in the immediate vicinity of the house, but *carried to a drain or*

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* A reward might be offered, sufficient to tempt the most capable persons to compete in designing model dwellings of the various classes required.

† In the large native houses one window or the door would open naturally on the inner court, the other on the outside wall of the house.

dust-bin respectively and there deposited. (7) The earth round the dwelling should be *well beaten down* and a *small channel made leading to the ditch or drain at the side of the road,* for disposing quickly of the rain water as it pours off the roof. (8) The house should be *opened up as much as possible, morning and evening,* to allow of free perflation. (9) Its exterior should be *whitewashed* as often as necessary to keep it cool and clean. (10) The latrine must be *outside* the general building, with an *impermeable floor* of asphalte or cement, if possible,* *easily accessible from behind* for the sweeper, *cleaned daily,* and with a door and window large enough to allow of *plenty fresh air and light* gaining admittance. (11) Whilst a few plants and small trees in the neighbourhood of a house are pleasant, there should be *no interference with the free passage of fresh air and light to all parts of the dwelling,* and all animals such as cows, ponies, fowls, etc., should be *separately housed outside the house and its enclosure.* (12) The occupants of the house should be *limited to the proper number,* and the unhealthy and objectionable practice of letting rooms to various families prohibited.†

ENCAMPMENTS OF THE NOMADIC CASTES—GIPSIES, PILGRIMS, ROAD COOLIES, ETC.

Nomadic Castes.—This is a matter that requires considerable attention being paid to it and receives but very little. There are, in India, numerous tribes or castes who lead a roving, nomadic life and settle down, in the course of their wanderings, for a longer or shorter time, on any piece of open ground they take a fancy to. The best

* Tarred chatties make the cheapest suitable form of receptacle. Two should be placed, one in front of the other, so as to receive and keep separate the liquid and solid excreta. Of course if the latrine communicates with a *pucka* open or closed drain, a sloping impermeable floor is all that is necessary. Cesspools, *khalcoovas, sundasses,* etc., are quite inadmissible.

† The extent to which this practice obtains in some places is almost unbelievable. Every available room and corner is 'let,' and the whole place being screened off with *tatties,* etc., at various angles, ventilation is impossible. In addition, each party does its own cooking in the one room or corner of the verandah belonging to it, whilst one filthy latrine does duty for the entire establishment.

known are probably the *brinjarries* or true gipsies and the *dhers* or *wadders*, the tank and well diggers of Southern India. Besides these, there are others, such as the tribes with large flocks of sheep and goats, etc., etc. The gipsies usually erect rough tents made of skins and cloths supported on a framework of sticks, whilst others build bell-shaped or dome-shaped hovels of mud, bamboo matting, palm leaves, etc. These people are a standing menace to the health of a community and have been repeatedly the means of spreading disease from one locality to another.* In the event also of cholera appearing in any town it is certain to find an especially congenial home in any place long-occupied as an encampment by one of these castes. The people themselves generally pass the greater portion of their lives out of doors, and those that survive the perils of infancy often live to a great age. Being, however, as they are, extremely filthy in their habits and surroundings, special attention should be devoted to them by the municipal authorities, and they should not be allowed to pick and choose the sites of their temporary habitations but be made to settle on selected pieces of ground and be subjected to regular inspection, under penalty of having to 'move on' to another district.

Pilgrims.—Somewhat allied to these in point of habits are the crowds of pilgrims that infest the great highways to celebrated shrines, such as Puri, Hurdwar, etc. They mostly move by night and settle down at sunrise like a swarm of locusts in the outskirts of a town or village, occupying the regular camping place without fear of molestation. The consequence of such a custom is that on these principle highways the best camping places are in a chronically filthy condition, the ground sodden with excrement and the water supplies contaminated, so that in the case of regiments or other bodies of men travelling by the same road, cholera, dysentery and other diseases suddenly make

* As small-pox has lately been spread in England and typhus fever in France by wandering tramps and mendicants.

their appearance and work dire havoc.* Such conditions prevail especially where the road passes through the territory of semi-independent rajahs, and the risk of encamping a body of four or five hundred men and several hundred women and children on such plague-spots is very serious. In former days, when regiments were constantly moved from one station to another by road instead of by rail, considerable care was exercised in the up-keep and sanitation of camping grounds, but since the construction of railways throughout the land the precautions taken have diminished whilst the evils remain. Consequently, those in medical charge of troops or other bodies of men marching by road must take great trouble to see that no place habitually used as an encampment by pilgrims, caravans, etc., is chosen, save under dire necessity, for occupation by those in their medical and sanitary charge. Similarly, the sanitation of the reserved camping ground near any town or village should be carefully looked to by the civil authorities, and a special piece set apart, with its own water supply, for those who may be expected to be reasonably clean in their habits.†

Construction coolies.—Still another very important branch of this subject is the selection of the site for and the erection of buildings meant to be occupied, from several months up to one or two years, by gangs of workmen and coolies employed in the construction of roads, railways or other public works. These buildings are often raised on most defective situations and constructed of most wretched material, so that the unfortunate occupants fall victims with the utmost certainty to any prevalent disease; and

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* *E.g.*, the road from Central India leading to Puri on the East coast, near Cuttack, was (1888) infested from end to end with bands of pilgrims, the consequence being that, in many cases, the only suitable encampment for the regiment with which the writer was marching, was quite unusable and had to be passed by for another in many ways defective, particularly as regards water supply.

† A great deal depends, of course, on the amount of interest in sanitation taken by the Commissioner or Collector of the district and his sanitary advisers. In one district the camping places will be models of cleanliness whilst in the next the reverse may obtain.

not only so, but owing to their poor clothing and diet, the rigour of the weather during the rainy or cold seasons, the absence of all proper ventilation in their lines at night, and last, but not least, the feeling of home sickness or nostalgia they suffer from so keenly, it is by no means uncommon for some disease such as epidemic pneumonia, scorbutus, typhus (?) or other fever to break out amongst them and help to swell the already large number of deaths. Before a single foundation is dug or a single cooly imported, the site, plan of the buildings, available articles of food and clothing and their price, and all other essential details should be the subject of careful and *responsible sanitary enquiry.**

CAMP LIFE IN TENTS.

In choosing a site for a pitched camp, the same precautions are necessary as on other occasions, with regard to drainage, water supply, etc. On arrival, the first thing is to ascertain the nature and distribution of the water supply and to make arrangements by which the purest water will be reserved for drinking purposes alone. A small amount of purified water should always be carried,† so as to obviate the possibility of having to drink from a doubtful source. Tents are best pitched in a place not recently occupied by other persons, on gently-sloping ground free from brushwood, but well-shaded by large trees. Ventilation during

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* It is the old, old story of good sanitation being the truest economy in the end. In addition, the sacredness of human life needs to be constantly impressed on officials and it should be understood clearly, and *acted upon*, that the immediate head of the works or operations is *directly responsible for the lives of those under his charge*, from the greatest to the least, and that unless he can show by documentary and other evidence that he did his best to prevent loss of life from accident or disease, the consequences will be very serious for him. I have seen coolies and camp followers eating, sleeping and living perforce under conditions such as no man but a savage would allow the meanest beast of burden to exist for a day. That such a state of things is a disgrace and, in the end, infinitely more costly, admits of no argument. Neither the training of an engineer nor of a medical officer, pure and simple, will make an efficient sanitary officer, as is too often assumed. Special training and experience are absolutely necessary. On the other hand, the coolies themselves often object to any ventilation, etc., most strongly, and will come in a body and petition against any windows being made in their lines!

† *v.* p. 96.

the night should receive careful attention,* and in the day time, when empty, the tents should be opened up as much as possible to allow of free perflation.

If intended to be occupied for more than one or two days, the encampment should be carefully arranged so as to keep the dwelling tents to windward† and to have the kitchen, servants' quarters, latrine tents and animals quarters all separated by proper distances. Any servant, after due notice given, found committing a nuisance near the camping ground should be punished. After a few days occupation the tents should be struck and re-pitched on fresh ground, unless the greatest care has been exercised in regard to sanitation. Further details as to arrangement, drainage, cubic space, etc., will be found under military hygiene.‡

HOSPITALS.

For General and Special diseases.—These, in common with jails and barracks, are commonly built more carefully and of better materials than ordinary dwellings, and in addition they are more strictly looked after with respect to sanitation and repair. The form of building most suitable as a dwelling-place for a number of sick persons has received a very large amount of attention from architects, medical men, nurses and many others, and hospitals are to be found scattered through the great cities of the world of every conceivable form and structure.§

With regard to details of construction, the directions given for the building of an ordinary house apply in similar manner, but there are one or two additional points requiring mention. In designing any hospital the architect

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* A few years ago, two native *shikaris* on the Nilgiri Hills closed their small tent at night and kept a pan of hot charcoal beside them for warmth. Next day they were both found dead, having been poisoned by the carbon monoxide given off from the burning charcoal. *v.* p. 11.

† Except in the case of hot land winds or wind blowing from a malarial swamp.

‡ *v.* Part IV.

§ *v.* The magnificent work by Burdett, lately published, on the Hospitals and Asylums of the World.

requires to keep two things prominently before him, *viz.*, the necessity for *very free ventilation* coupled with *compactness of the building*, so that the staff for attendance on the sick may be no larger than absolutely necessary. But of all things, pure air is *the* most essential requisite for every hospital.

It is not only the fact that there are a great many people occupying one building that is so important, but that these are *sick* people; and this for a two-fold reason. In the first place, each person requires an additional amount of pure air to aid him in the process of recovery; in fact he should be bathed in pure air. In the second place, the air of a hospital becomes much more readily loaded with impurities from the persons of the sick, their bedding, clothes, dressings, wounds, utensils, excreta, etc., and these impurities may be and often are of a specific nature, so that if not speedily removed they may be the direct cause of spreading tuberculosis, pyæmia, erysipelas, hospital gangrene and many other diseases. Many diseases which formerly devastated hospitals and made them literal death-traps, have now, by ventilation and cleanliness, been almost entirely banished.*

Before, however, taking up the consideration of the most approved designs and arrangements in modern hospitals, reference must be made to some of the work done in past years in connection with the reform of Indian hospitals. Foremost among names associated with such work stands that of the noble-hearted Florence Nightingale who, at the request of the President of the Royal Commission on the Sanitary State of the Army in India, contributed a most valuable report on this subject.† After discussing the

* The subject of the reform of hospitals generally cannot be further considered here. It is of absorbing interest and affords most conclusive testimony of the value of true hygiene. Those wishing further information may consult the articles in Parkes' Hygiene and Stevenson's and Murphy's Treatise and the references contained therein; also the comprehensive work of Burdett, before referred to.

† Entitled, "Observations on the Sanitary State of the Army in India." She also wrote another most valuable work, "Notes on Hospitals."

various weak points in the surroundings, accommodation, mode of life, etc., of British soldiers in India* she goes on to discuss the question of hospitals in that country. Some of the statements are almost unbelievable, but they are all taken from the actual reports sent in by medical, engineering and other officials on the spot.—"The 'sanitary state' is generally represented as 'good,' although at the same time we are told, as in certain cases, that the hospital is 'unfit for accommodation of European patients;' or that 'epidemic disease has appeared in it;' that 'sores become erysipelatous;' that, as at Bangalore, 'one of the flags [stones] in the floor being removed, the smell from the opening was so offensive that the surgeon was obliged to run;' that 'gangrene and phagedœna have appeared, when the hospital was crowded;' that 'the privy is a nuisance to one ward;' 'that the cesspools are always more or less offensive;' that the 'out-houses are in a very dirty and unwashed condition.' At Muttra the contents of the latrines are 'carted away every morning for combustion in one of the many brick kilns which surround the station, and help to poison the air.' At Madras, the sanitary state is called 'good,' and the Commander-in-chief himself adds, 'if the vile, stinking river Cooum were not under the very noses of the patients.'"† * * * "Bangalore gives a reason for the covered way to the latrines, which we should never have thought of: 'it is a covered place for exercise'" (!) * * * There is no instance, except at Wellington, where the hospital, if on one floor, as is usual, is raised from the ground with any current of air beneath. These hospitals are stated as at Bangalore, to be 'always damp in wet weather.' And often the floor is merely the ground bricked over. Rangoon and Tonghoo live like the beavers, and raise their barracks and hospitals on piles, with free passage for air underneath. The consequence is that in those jungly swamps, they are more

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* *v. post.*, Part IV.

† The 'vile, stinking Cooum' is still under the noses of the patients in both the General and Station Hospitals, Madras; and is probably now more vile and stinking than ever it was.

healthy than at most other Indian stations where the men sleep close to the ground." * * * "The wards can never be said to be light or airy; 'as a general rule, hospitals are badly-lighted and gloomy;' doors are more common than windows. And these doors, when closed, leave the ward, if not absolutely dark, yet absolutely dismal and close. Indeed a dark ward must always be a close ward. Or 'light enters from a couple of panes in the doors near the top, and when closed, darkness is almost complete.' There is in Indian hospitals hardly a room light enough to perform a surgical operation. And operations, it is stated, have to be performed in the verandahs. The inner verandahs are generally used for sick whenever more room is wanted: the outer ones sometimes cut up for lavatories, destroying what ventilation there is. The superficial area *per* bed is almost invariably too small, and the wards almost as invariably too high; the result to the sick being that, with an apparently sufficient cubic space, the surface overcrowding is excessive. One of the worst examples of this is the recently constructed hospital at Trimulgherry (Secunderabad) which consists of three wards, two of which contain no fewer than 228 beds each; the wards are 42 feet high, and afford 1,001 cubic feet per bed, but the surface area per bed is only 24 square feet." * * * "All the defects of the barracks re-appear, and with worst consequences, in the hospitals: *viz.*, bad water supply, bad ventilation, no drainage (Ferozepore says 'drainage not necessary'), offensive latrines, so offensive indeed that the patients have sometimes to leave a particular ward, no means of bathing and hardly any of cleanliness." The food, cooking, clothing and attendance are all shown to be faulty.

Native hospitals are "generally nothing but a shed, perhaps a 'gun shed,' or a 'cattle shed' as at Kolapore, converted into a hospital, where the sick receive nothing but medicine. The patients cook their own diets, eating and drinking what they please." * * * "There are no conveniences; sometimes the sick go home to wash or bathe

themselves in a tank." * * * "It is supposed that 'caste' prejudices are such as to prevent native hospitals being properly built and supplied with requisites for the sick. But this has to be proved by giving natives a properly constructed and provided hospital. There are plenty of 'caste prejudices' in this country [England] against good hospital construction; but good hospital construction advances nevertheless."

Much more to the same effect wrote Miss Nightingale, amply supported by the fact of the case. Have these defects been remedied since that time? A few of the most glaring certainly have, and in the case of some of the largest civil hospitals and the chief 'station' hospitals a high degree of construction and management have been maintained, but there is no doubt that with regard to many of the larger and nearly all of the smaller hospitals, most of the above deficiencies still obtain. The ordinary native regimental hospital is the same as it was thirty years ago and the habits and customs pertaining thereto but slightly better. There is no doubt, however, that 'caste prejudices' have a good deal to do with the latter and have prevented the native—soldier and civilian alike—from enjoying many easily made improvements in regard to his surroundings. It is wonderful, all the same, how the nettle of caste, if firmly seized, ceases to sting, and how those who at one time constantly asserted that they would be ruined body and soul if they were not allowed their own way of doing things, have ultimately, if taken the proper way, been loudest in their praise of the new arrangements.

Hospital Sites.—As regards the site of a hospital, the elements which ought to determine its position are the following:—*

First, and before all others, purity of the atmosphere.

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* Miss Nightingale. Notes on Hospitals, p. 29.

Second, the possibility of conveying the sick and maimed to it.

Third, accessibility for medical officers, and for the friends of the sick.

Fourth, convenient position for a medical school, if there be one.

Only the first need be considered here. On this subject a recent writer,* taking the Jamsetjee Jejeebhoy hospital as a type, "and by no means the worst one," of a large hospital in a large city, remarks: "The hospital is not crowded by surrounding buildings, and has a good margin of land about it. It stands, however, in the midst of a densely built and densely populated part of Bombay."

"Between it and the sea, in the direction of the prevailing west wind, lie $1\frac{3}{4}$ miles of land, part of which is marshy and part densely populated by the poorer classes; and the wind, blowing over the district from the Arabian Sea, loses a good deal of its purity. The action of the wind blowing over a town is not that of one solid plane object sliding over another. That part of the wind in contact with the houses on the ground eddies and rolls on its passage, taking up many impurities on its way. The vertical circulation that is set up by the sun's heat absorbed by the surface of the ground and by buildings, carries up foul air from alleys and gutters, and the more slowly the wind travels over such a district, the more of these impurities it will take up. Passing over houses and coming to an open space, the current of air descends until it meets with new obstructions."

"In this manner the hospital with its wards raised slightly above the ground level, is ventilated with air of considerably reduced purity, assuming the sea breeze to be the standard."

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* Wallace, *op. cit.*, p. 214.

A hospital, then, requires not only a site fulfilling all the usual conditions, but one to which there is unlimited access of really pure air.

Hospital Designs.—Next, the design of the building has to be considered. All modern hospitals,* of any size, are constructed on the principle of separate blocks or *pavilions* joined together by a long passage or corridor. Each of these pavilions contains one or two wards (if two-storeyed), rarely more, and has belonging to it a complete set of rooms for the use of the medical officer, nurse, etc.; for cooking special dishes; a waiting-room for patients; a linen-room, etc. These are generally arranged so as to occupy the space on either side of the short passage leading from the main corridor to the ward. Then comes the ward itself, and finally, at the far end of the ward, the bath room and lavatory on one side, the latrines on the other, both these latter being more or less completely isolated or cut off from the general ward. This arrangement can easily be understood from the annexed plans. The pavilions may be placed side by side or in line, according as the hospital is large (over 100 beds) or small, and are planned to allow of free perflation by means of cross ventilation, abundant light and easy communication. The distance between the pavilions should be *at least* twice their height in a good situation: no hospital should be built in a bad situation. The details of size, number of wards, etc., cannot be considered here, but no ward should contain more than 20—30 beds, and there should be smaller wards of 4 beds in the pavilion for special cases requiring extra care, warmth or coolness, etc.

Ventilation.—The means of ventilation, the amount of air supply, cubic space and superficial area have next to be considered. This has already been done to a certain extent and the rules there given may be referred to.† One of the commonest errors in this country, as in the case of the hospital at Trimulgherry, before referred to, is to

* With few exceptions.

† *v.* Chap. I, pp. 23, 33.

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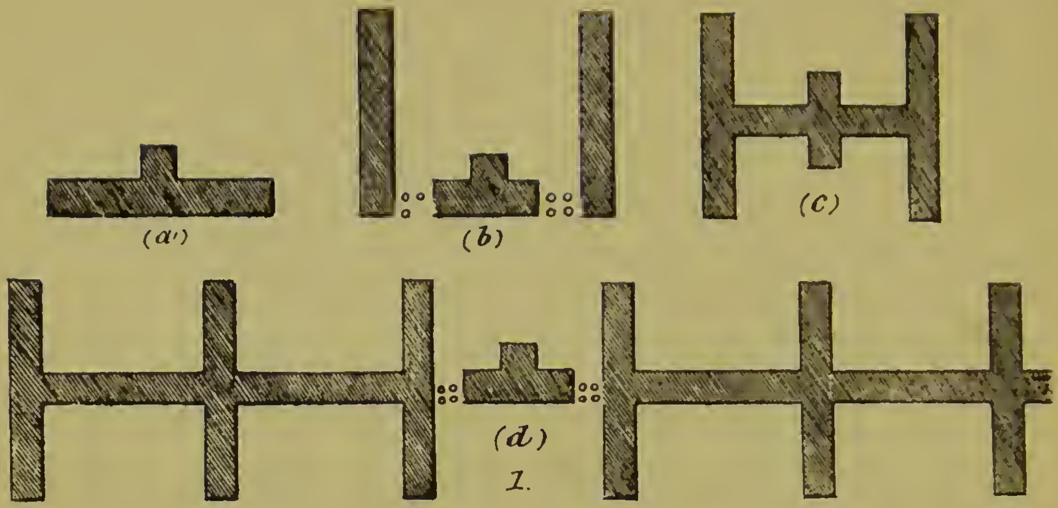

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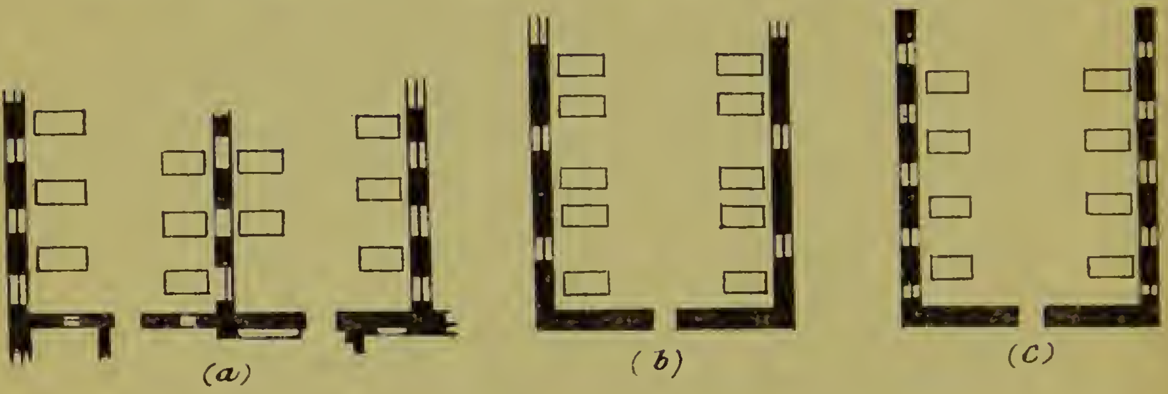

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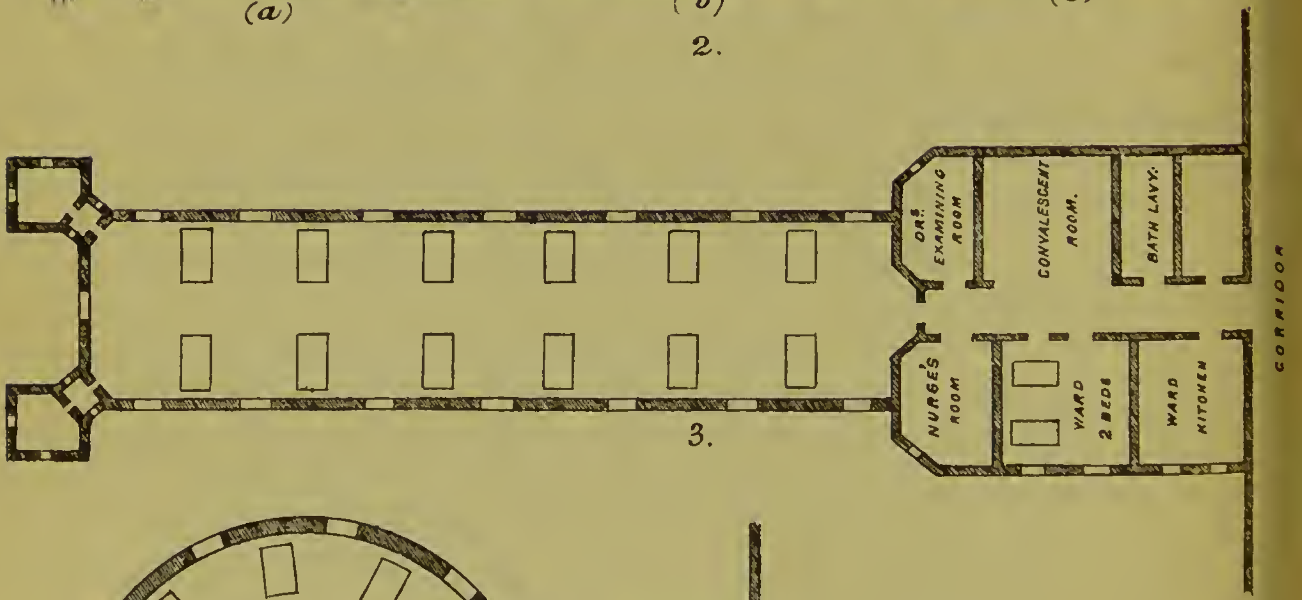

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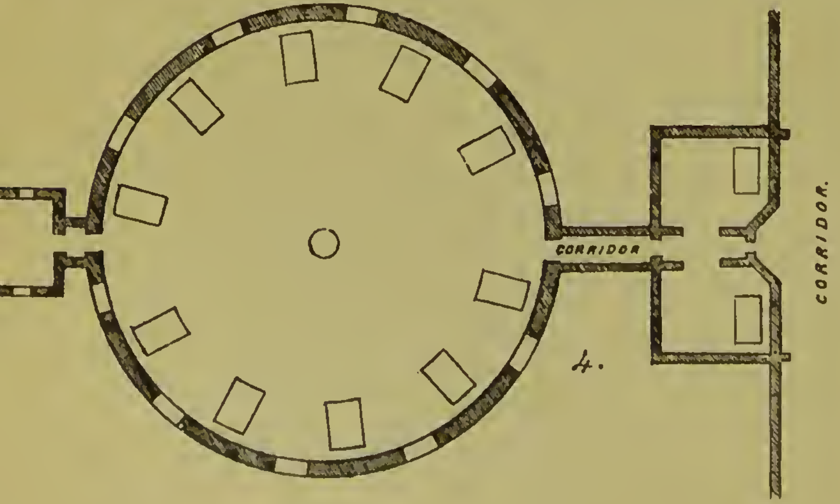

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C. PACZENSKY LITH.

To face p. 256.

PLATE XIV.

HOSPITAL AND WARD PLANS.

Figure 1. Diagrams illustrating Designs for Hospitals on the 'Pavilion' System. In each figure there is a Central Administration Block with Single, Double, or Multiple Pavilions in connection therewith.

Figure 2. Plans of Wards, to shew various Arrangements of the Beds. In (*a*) there are double wards (as at Madras General Hospital) in (*b*) there are two beds between each window; in (*c*) the proper arrangement of beds is shown. (After Burdett.)

Figure 3. Plan of a Ward in a Modern Hospital arranged on the pavilion plan. Each pavilion contains one, two, or three such wards, according as it has one or more storeys. The latrine and bath room are seen projecting from the outer end of the ward, with cross ventilation between. Each ward possesses its own Examining Room, Nurse's Day Room, Ward for Special Cases, Kitchen for preparation of Special Food, etc., Convalescent Room for use of Convalescent Patients—a most important provision, Bath Room for use of Convalescents, etc., etc. The wards are connected with each other by means of long and airy 'corridors' or passages running throughout the whole length of the building, in which the air is kept fresh and warm (if necessary), thus affording an excellent place of exercise for those who are well enough to enjoy it.

Figure 4. Plan of Circular Ward as adopted in some Modern Hospitals. The advantages of this form over the ordinary oblong pavilion are by no means evident; though it is conceivable that in a very stagnant tropical climate the circular pattern might be cooler and more easily ventilated. In this latter case the central ventilating shaft (shewn in plan), might be carried well up above the roof and warmed by sun heat in the day time and by a small charcoal fire near its outlet at night.

build lofty wards and to fill them with beds so that each patient has about 25—30 sq. ft. of superficial area instead of at least 80—100 sq. ft. Such a mistake must be carefully avoided. For supplying fresh air, most modern hospitals are so arranged that the wards can be ventilated by simple perflation, during fine weather, and by artificial means with warm air, during cold or wet weather. No hospital in India is as yet supplied with pure, cool air, though it is highly desirable that they should all be. Instead of the weary, sleepless nights so trying to every one, but much more to the sick, to whom indeed it often means death, there would be the unspeakable blessing of cool, fresh air bringing with it the much-needed sleep and renewal of the bodily powers. It is earnestly to be hoped that this subject will shortly receive the attention it deserves and that once hospitals have been cheaply and effectively supplied with cool, pure air, the same benefit may be extended to dwelling houses, hotels and other habitations.* No method of natural ventilation is sufficient for Indian hospitals, save possibly for the cold season,

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* Mr. Wallace, *op. cit.*, considers this subject carefully and has some pertinent remarks thereon. "It is unfortunate that in spite of the large sums that have been spent in India on the construction, furnishing and maintenance of hospitals, the subject of ventilation has been almost entirely neglected. If ample cubic space per patient, and plentiful communication with the outer air were sufficient, there is little to complain of, but if air for breathing may be regarded as a medicament which should be supplied of the best possible quality, to the patient, there is scarcely a hospital in the country that is not open to the charge of administering an inferior article." * * * "The quantity of air passing through the wards depends almost entirely upon the velocity of the wind, and when we follow up the question of air supply to single individuals, all idea of systematic ventilation is lost." * * * "The absence of data regarding the impurities of the atmosphere, and indeed of air analysis of any kind in India, is a most regretable circumstance, as it prevents any calculation as to the exact minimum quantity of air that should pass each patient *per* hour in the hospital. Even in Bombay where immense sums have been expended in sanitary work the Corporation refused to sanction the expenditure of Rs. 300 a month for some months in air analysis which would have been of the greatest value in furnishing a true and reliable basis for many of the works on which the health of the people depend." In his thoughtful work, Practical Observations on the Hygiene of the Army in India, Stewart Clark, M.R.C.S., late Inspector-General of Prisons, N.W.P., described in detail a proposed system of ventilation for hospitals, barracks, etc. It was tried in Agra jail (*v.* footnote, p. 29) but I have been unable to obtain any information on the subject beyond the

and it frequently happens that during monsoon time the whole building has to be closed for many hours on one or both sides, by reason of the violence of the wind and rain. In such a case, the heat and stuffiness become very trying *at once* and, owing to the darkness and absence of perflation, the mosquitoes swarm from every corner and worry the patients still further.

The actual form of the hospital in India should be that of a series of blocks or pavilions as before described, but the details of the design must vary very much according to the intended size, the money available, the local climate and many other conditions. Coolness of the building is of course important, but it must be remembered that coolness at night is more essential than coolness during the day, so that the walls must not be made too thick nor the eaves too low. Broad, shaded, verandahs* form useful and pleasant lounges, and the exposure of the hospital should be such that the direct rays of the sun fall principally on the ends and not on the sides of the pavilions. With a system of efficient artificial ventilation giving an abundant supply of

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fact that it has fallen into disuse 'apparently because it did not prove a success.' It is to be feared that this is an example of a *laisser faire* policy adopted by a successor of the energetic inventor. It could be applied and worked much more easily than formerly, in large towns, by the use of a small gas engine or water motor. "The tunnel plan was tried some years ago at Agra and was not well thought of. But everything depends on the mode of making the tunnel." (Parkes-Notter, p. 522.) It must go deep enough and be absolutely impervious to ground air. Clark's method should be carefully examined and modified if necessary, by a practical Sanitary Engineer and then tried thoroughly at some large hospital or barracks. When the external atmosphere is warm and moist at the same time (the most trying condition of things in this country, especially for the sick and debilitated), some special method of cooling it would have to be invented, but for ordinary use, *khas-khas* screens or metal shafts covered with moistened cloth (*v.* p. 227) would be quite sufficient. The subject is worthy the attention of practical engineers, *i.e.*, *after* means and opportunity have been given by the authorities for the obtaining of data to go upon. Mr. Wallace's proposals (*op. cit.*, p. 219, *et seq.*) are of much the same nature as Stewart Clark's, or even simpler. The cost would be very small, not merely relatively to the advantages gained, but actually, and as compared with the system of steam-driven punkahs (the best of their kind in India) in the General Hospital, Madras, infinitely better for the patients.

* The verandahs should have openings in their highest parts for ventilation, and, if necessary, shafts projecting upwards from the openings. Double verandahs are a mistake and interfere seriously with ventilation.

cool air, the greater attention can be paid to securing a cool building; but in the ordinary Indian hospital, as in the bungalow, the small size and paucity of the windows, the deep and low verandahs mean the sacrifice of light and pure air in order to secure a slightly lower temperature. Of the two evils, slightly greater heat is far less injurious than impure air and the absence of sufficient light.

All hospitals in the plains should be entirely white* with the exception of the *chicks* (rattan blinds), windows and doors which should be green.† The floors must be made of some impermeable material, cement or concrete being the best.‡ Asphalte is fairly good§ and is cheaper. The impermeable wooden floors so much used in colder countries look well but are unnecessary in India, where coolness not warmth is the *desideratum*, and an Indian hospital should have as little wood about it as possible. The walls must be of impermeable|| material also, either

* This important point is emphasised by Wallace, *op. cit.*, p. 195, *et seq.* With reference to roofs, he says, "A terrace roof, as generally constructed, offers very little advantage over the tiled roof. It is white at first, when new, but it soon becomes black with fungoid growths, and, being nearer the floor than the tiled roof, is often hotter. Being of greater mass, it cools more slowly at night. The temperature has been observed as high as 120° F. on the parapet of a terraced roof which had been blackened by age and fungoid growths." * * * "Whitewash will only adhere to a clean surface: if applied to a surface blackened by fungoid matter, the lime will scale off."

"An excellent limewash that will adhere to stone, iron or glass may be made by mixing 10 per cent. of any common vegetable oil with the lime while slaking. The lime to be weighed dry. If the oil does not saponify and incorporate with the lime, it must be boiled a little until the oil disappears. Castor oil must not be used. The oil forms with the lime an insoluble soap, which, when once dry, will not wash off with heavy rain. It must be strained and applied in the usual manner." A reduction of 26° in the temperature was obtained by means of a coating of this substance applied to the corrugated iron roof of the Bombay Tramways Company. It cost 11 annas *per* 1,000 square feet, labour and materials included.

† If exposed to direct sunlight, the outer sides should be painted white, so that the incoming air is not heated.

‡ Parkes, on the strength of a remark by Chevers, apparently, objects to cement as wearing into holes and being dusty; but good cement, well laid and of sufficient thickness, is certainly better than anything else for use in the tropics.

§ One disadvantage is that for some time after laying the asphalte, it blackens everything that comes in contact with it, such as the feet of the patients, and these in turn dirty all bedding, etc.

|| *v.* p. 233. Certainly not permeable as proposed by various writers.

cement or polished chunam, or in special cases, glazed tiles set in cement. Probably the most effective wall would be white or coloured tiles in cement to a height of four feet from the floor all round the ward with cement or polished lime above that. Ordinary plaster, being absorptive of dirt and moisture, makes the worst wall; in this case, the plaster should be rubbed smooth and covered with several coats of oil paint. A good idea is to join the walls with the floor and ceiling by a concave moulding so as to obviate angles for dust and dirt to lodge in. The best ceiling is made by filling in the spaces between the beams with cement and painting the whole of a white colour with oil paint. If pictures are hung on the walls, picture wire must be used, not cord, and the frames must be quite simple. All pictures, etc., should be taken down once a month and dusted outside the ward.

It is impossible, in this manual, to go into the various details of hospital hygiene, but it must be remembered that no detail, however trivial apparently, is too small to be neglected. The occupants of the hospital are sick people fighting for life, as it were, and every thing should be so ordered and carried out as to give them all possible help in the struggle. Their beds, bedding, clothing and food, their hours of rising* and retiring to bed, their exercise and amusements, are all to be carefully planned and looked after, and it goes without saying that the practical sanitation of the whole place should be as perfect as skill and zeal can make it.

One important point remains to be noticed and that is the position, in general hospitals, of the wards which are

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* A most injurious practice for the sick is confining them rigidly to certain hours for rising, sleeping, eating, etc. Regularity is of course essential both for patients and their attendants, but wherever necessary, permission to remain in bed, to smoke in bed, and any other little indulgence, should be freely given so as to avoid undue weariness, depression or irritation. The golden rule to 'do unto others as we would be done by' has special application here. The staffs of hospitals, from the medical officers to the sweepers, are so often overworked, however, that it is most difficult and requires the greatest self-denial, to invariably carry out this moral obligation.

to be occupied by natives. These latter, poorly clad and miserably nourished as a class, are very sensitive to anything like cold, and if placed in wards situated, say on a third storey, are sure to suffer during rainy or cold weather, *i.e.*, for more than seven months during the year. Whilst the wards should have plenty of fresh air, continually renewed, it is impossible, so long as direct perflation is the method of ventilation in use, to insure a sufficient supply of such fresh air during wet or cold weather, without the native sick being injuriously affected.* Finally, no hospital should have double wards, as it were, so that there are four beds in a straight line between each window: in such a case the ventilation is certain to be deficient.† There should be a double line of beds only, a low window being placed between each pair of beds, and no beds should be allowed at the ends of the ward. The best wards are frequently spoilt by overcrowding with 'extra' beds, a plan which is an injustice both to the patients already in occupation and the hospital staff, the latter being calculated for the authorised number of sick and quite insufficient for such additional work.

It is almost unnecessary to add that the admission of infectious cases such as cholera, small-pox, measles, etc., to the grounds and wards of a general hospital, as is done at Madras and probably elsewhere, is a direct violation of

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* A good instance of this has occurred lately at Madras General Hospital. Two very stuffy and defective wards on the ground floor were turned into store rooms and the patients transferred to new wards in the top (third) storey of the building. During very hot weather the patients like these wards and do well, but whenever it is cold or chilly during rain, they begin to dislike them and that their dislike is well founded is shown by the fact that various diseases such as nephritis, bronchitis, asthma, rheumatism, etc., get worse or improve very slowly. The patients, of course, get the nurse or ward attendants to close all doors and windows on one or both sides, whenever they can persuade them to do so, so that ventilation speedily ceases and the other cases suffer. If a third storey must be constructed, it should be reserved for European patients only.

† This practice obtains at Madras General Hospital where, punkahs and all notwithstanding, the air, in still weather, stagnates about the arches in the centre of the wards (*v.* fig. 31, in Miss Nightingale's Notes on Hospitals). Otherwise the plan of this hospital is much better than those of others in India and approximates to the pavilion system. The same defect may be seen in the London Hospital at Whitechapel in London.

the simplest rules governing sanitary measures for the prevention of disease.

HOSPITALS FOR INFECTIOUS DISEASES.

Cholera and small-pox are the chief diseases which should be treated in separate hospitals in this country. Enteric fever ought probably to be treated in such hospitals, or at all events in special wards in general hospitals. In England, cases of typhus and scarlet fevers are sent to 'infectious' hospitals and cases of diphtheria should be sent also. There are many so-called hospitals for lepers in India, but these are really homes for incurables and as such do not fall to be specially considered here.

The principles which govern the construction and management of these hospitals are the same as for general hospitals, but there are some important practical differences due to the element of contagiousness and to the tendency to epidemic outbreaks.

In the first place, the site must be even more isolated and apart from other dwellings than that of an ordinary hospital, yet must be easily accessible for the speedy conveyance thither of the sick. The next question to be settled is whether the hospital is to be a permanent or a temporary one. This has been hotly debated in many countries, the true solution of the difficulty being evidently as follows: Large towns should each have a hospital of their own, smaller towns or the villages of a district should unite in having a common hospital, each town or village paying a *pro ratâ* share of the cost of up-keep. In both cases, as described below, the hospital should be a permanent one of small size, with a prepared site large enough to allow of considerable extension at short notice. Unfortunately, in this country, poverty of the people and the terrible rapidity with which cholera carries off its victims makes the latter plan unfeasible, at all events for the present, and all that can be done is to arrange for smaller towns having temporary hospitals, when necessary, constructed as afterwards described.

For large towns provision against outbreaks of infectious disease should be made thus. Having calculated the ordinary requirements of the town in the way of accommodation for cholera, small-pox, etc., and the probable requirements in cases of epidemic outbreaks, a suitable site is fixed upon, large enough for any possible extension of sick accommodation. This site is then prepared with reference to drainage, water supply, conservancy, etc., as if a large permanent hospital was about to be erected, and at a suitable spot, an administrative block for the use of the medical officers, nurses, ward attendants, etc., is built of most approved materials and design. Near this block one or two other small pavilions of one, or at the most two storeys, are erected for the reception of patients, these latter being isolated in separate wards according to sex and the disease they are suffering from. In addition a couple of small pavilions are built for the reception of 'doubtful'* cases, male and female. Thus the permanent hospital itself would consist of (*a*) an *administrative block*, arranged according to any desired plan; (*b*) *four small blocks* containing say, four wards of six beds each, *viz.*, *two separate small-pox wards*, for male and female patients respectively, and *two separate cholera wards*; (*c*) *two small blocks*, each containing an '*observation*' ward of four beds; (*d*) a *laundry* for washing all clothes, bed-linen, etc., to which must be attached a *disinfecting chamber*† and a *small furnace* for destroying fouled dressings, cloths, etc.; (*e*) a *mortuary and post-mortem room*; (*f*) *stables and coach-houses*, including accommodation for one or more special ambulance waggons;‡ (*g*) *lines* for ward coolies, dhobies, sweepers, etc.

The water supply must be good and ample, preferably

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* Most necessary in India, in order that patients suffering from violent diarrhœa may not be conveyed to cholera wards, as sometimes happens.

† *v.* Part III, Etiology and Prevention of Disease. The furnace might be of the nature of a small incinerator to be used for the destruction of all refuse matter, and placed in a special corner by itself.

‡ The hospital should be connected with the town by telephone to the 'central exchange' office or to the office of the M. O. H.

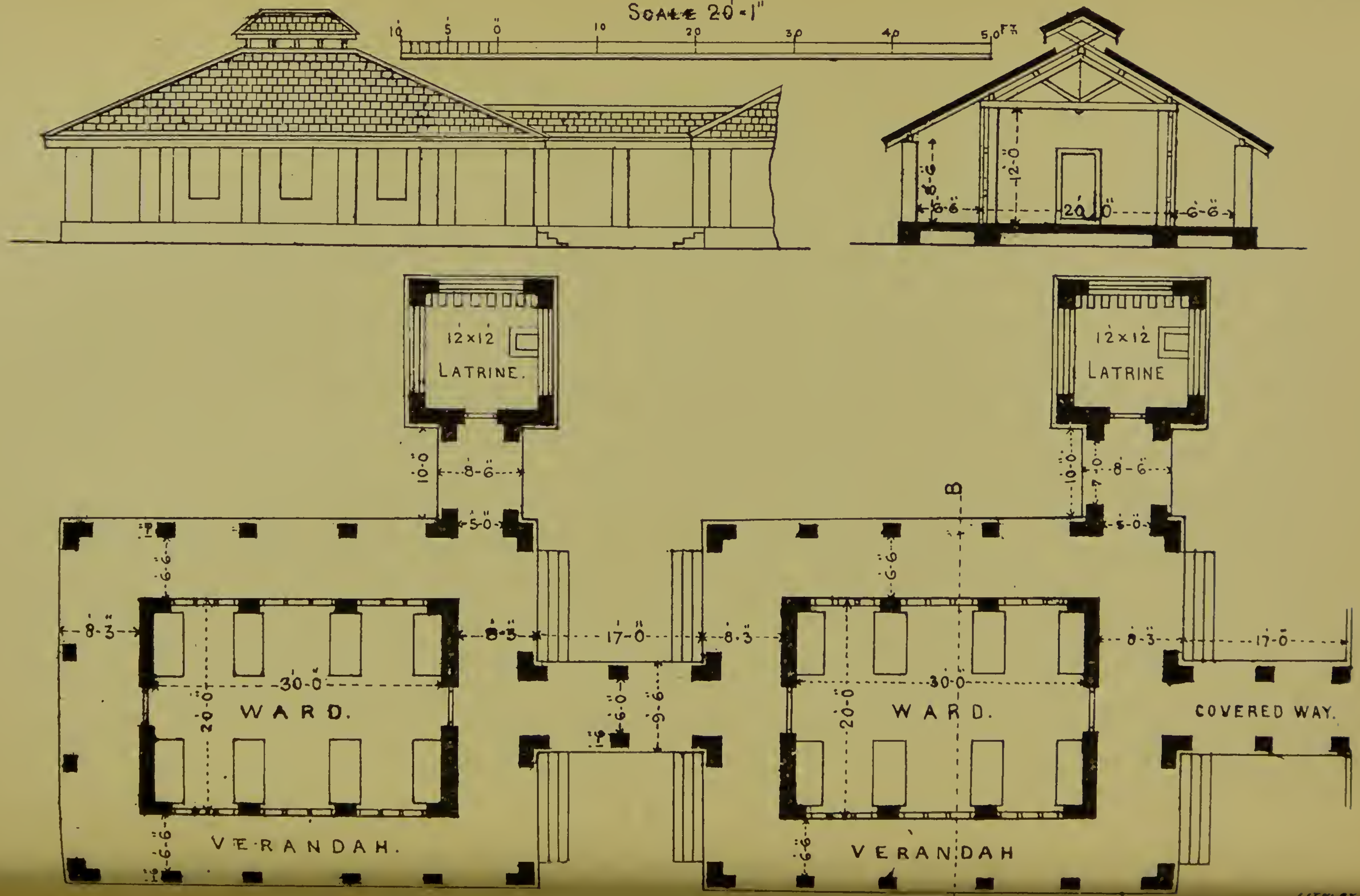
from a constant supply, and all arrangements for drainage, conservancy, etc., effective and on a liberal scale. The wards themselves should be large and well-ventilated, allowing the maximum obtainable of fresh air, cubic space and superficial area. Externally they should be whitened, and internally the walls, floors and ceilings must be perfectly smooth and impermeable. In addition, the doors, windows and other openings should be very carefully made so as to admit of complete closure and thorough disinfection at intervals.*

Having, then, made arrangements for treating the probable number of ordinary cases of small-pox and cholera, with observation wards for special cases and an administrative block large enough for emergencies, the next point claiming attention is the preparation of temporary buildings for the reception of numerous cases during a sudden outbreak. For such buildings the actual foundations alone need be ready prepared. The so-called 'contagious sheds' at the General Hospital, Madras, though not perfect, are a good example of the type of building required (*v.* description and plans). Each ward must, however, be completely detached save for a covered way, and no ward should contain more than six beds. The sheds are constructed of bamboo matting, which may be burnt after use, fitted on a wooden frame-work, and have ridge ventilation through their entire length in addition to windows between each bed. For convalescents there should be a dry, cool and pleasant place for exercise. The sullage water may conveniently be utilised for irrigating the compound† and so making it green and shady. Many other details require the most careful consideration, but for these, standard English works must be consulted and suitable modifications adopted. The patients, of course, should be admitted free of all payment and every inducement held out to encourage

* *v.* Part III.

† In such a case the quantity of water compared to the surface to be irrigated is so small that under-drainage is quite unnecessary, so long as the water continuously comes in contact with the roots of growing plants.

SECTION ON A.B. PLATE XV.



To face p. 264.

PLATE XV.

SHEDS FOR USE AS INFECTIOUS DISEASES HOSPITALS, ETC., IN THE TROPICS—SHOWN IN PLAN, IN SECTION, AND IN ELEVATION.

SPECIFICATION.—The wards to be 20′ wide, with verandah all round, about 8′ 3″ deep to edge: they will be connected by covered ways 17′ long and 9′ 6″ wide. Each Ward to have a latrine 12′ square, connected to it by a short covered way.

The sides to be of bamboo matting, except where piers are required to support the roof trusses. There will be a window between each pair of beds, also of bamboo matting. The piers and other walls will be of brickwork plastered and lime washed (cement facing preferable). The roof to be of Mangalore (or Allahabad) tiles supported by teak or any other approved country wood. Ridge ventilators should be provided. The floor to consist of a concrete bed 5″ thick, well-rammed and consolidated, and laid with bricks set flat in mortar; the bricks to be plastered with 1 part of Portland cement to 2 of sifted sand. The floor to be slightly sloped outwards to facilitate washing. The matting should be made in pieces of convenient size, to allow of its partial renewal where necessary. It should be completely renewed at intervals, and the whole of the woodwork scrubbed and disinfected.

The superficial area allowed per head is 75′ square, and the air space 1125′ cubic.

them or their friends applying for their admission. One difficulty peculiar to the country is the constant separation of the sexes in different hospitals. If this be considered insuperable,* the male and female wards may be kept quite distinct in their own compounds, the administrative block being placed between.

JAILS AND ASYLUMS.

A very few words will suffice for this subject here. Of late years an enormous improvement has taken place in both classes of institution. Originally, the only consideration in either case was the construction of a building from which escape should be impossible, and as a consequence, no attention was paid to ventilation, cleanliness or the many other points essential to healthy living, so that diseases of all kinds carried off their helpless victims. Typhus fever, in particular, was so common that it received the name of 'jail fever.'† "At the present time, however" says a well known authority,‡ "the prisons of this country [England] are proved by the most rigid statistics to be far healthier than our homes, and so-called preventable disease of any kind is of such rare occurrence within their walls, that when any isolated cases do appear they at once give rise to surprise, and are sure to call for inquiry."

For many years Indian jails have been models of cleanliness and, to one who can use his eyes, a visit to any of the great central jails will be worth more than pages of writing. They are commonly arranged on the 'radiation' plan, in which the numerous blocks or pavilions of one or two storeys radiate from a common centre, the whole being

* That it is not really insuperable, witness the present plan of uniting the male and female general hospitals at Madras in one building.

† "My reader" wrote John Howard, the philanthropist, who devoted his life to ameliorating the conditions of life of prisoners, "will judge of the malignity of the air in jails, when I assure him that my clothes were, in my first journeys, so offensive, that in a post chaise I could not bear the windows drawn up, and was therefore often obliged to travel on horseback. The leaves of my memorandum book were often so tainted that I could not use it until after spreading it an hour or two before the fire."

‡ Dr. G. Wilson, Hand-book of Hygiene, 6th edition, p. 10.

surrounded with a high double wall. This plan, of course, is not so good as the true pavilion system described in the section on hospitals, but it is impossible or, at least, extremely costly to build pavilions for the housing of one or two thousand prisoners. Again, the high surrounding walls make the place hot and interfere with its ventilation; so that these defects, combined with the relative overcrowding, constitute an undoubted evil, which cannot, however, be easily remedied save by *artificial* ventilation with pure, cool air.

Lastly, it is important to remember, and most particularly so during an outbreak of contagious disease, that the occupants of a jail are prisoners and as such, are liable to be more or less depressed and careless of their lives: great care must therefore be exercised to make them as happy as may be under the circumstances and to let them see that their lives are accounted of the same value as those of other people.* In the case of high caste people, especially, the sudden change from freedom to prison life, affecting both their mental and bodily surroundings, has frequently a most depressing and even serious effect, and they require careful watching for a considerable period.

Two points there are in favour of prison hygiene, *viz.*, the amount of free labour available, and the fact that the occupants are *made* to be clean and to live perforce amidst hygienic surroundings.

With regard to Asylums for Lunatics the conditions are much the same and plenty of free labour is obtainable, the regular employment and exercise being a most valuable part of the treatment in many cases of insanity. Many insane persons, however, are so unspeakably filthy in their habits that extreme care is necessary to prevent them rendering themselves diseased or being the means of communicating disease to others.

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* Of course without any of the foolish pampering of criminals which is becoming the fashion in the United States of America and elsewhere.

In countries not advanced in civilisation the treatment of the insane is marked by extreme cruelty, the result of ignorance, whilst in those highest in the scale everything is done to make their environment as pleasant as possible and to keep them in the best condition of body and mind.

BARRACKS.

More money has probably been wasted in India on this class of building than in any other country in the. world, and with less satisfactory results. The barracks originally constructed for the accommodation of British soldiers were apparently modelled on native dwellings so far as light and ventilation were concerned and had the general appearance of an elongated gunpowder magazine. Following upon the condemnation of these rudimentary structures, huge blocks of one or two storeys each were erected, at enormous cost, in the chief military stations. In the work of Miss Nightingale alluded to before, she shows how radically defective these enormous structures were and are, and the same means of information being available to the designers and other officials concerned in their erection, it is to be regretted that they should have spent and been *allowed* to spend, such vast sums of money to so little purpose.

"Generally, very little attention appears to have been paid to independent ventilation as a cardinal point of barrack construction. Doors and windows have been trusted to; yet they are so placed that men are often exposed in bed to hurtful draughts, and if shut, the fresh air is also shut out. Sometimes there is no glass in the windows, and when these are shut there is darkness as well as foul air. *A knowledge of the proper application of sanitary appliances to buildings in India appears to be as yet in its infancy.*"* * * * "At Fort

* The italics are mine, and these words are as true now in almost every case as they were thirty years ago. Those to whom the designing and erection of public buildings are entrusted are too often guiltless of any real training in sanitary matters, and the honest ones confess it. Every fault regarding

William, the Dalhousie barracks which are said to be 'perfect,' have *six* rows of beds between the opposite windows, 216 beds by regulation in each room, and three floors of such rooms. While it is added, '900 men' (300 men per room) 'are generally accommodated in the barrack without inconvenient overcrowding.' What is *convenient* 'overcrowding'?"

So also, Stewart Clark* wrote—"Whatever the construction of the barracks may be, if the atmosphere be hot, still and sultry, and the apartments large, and occupied by what is at present considered the full complement of inmates, they can *never be healthy* if provided with no better ventilation than can be obtained through natural sources."†

It may be taken as an axiom then, though many who have not studied the subject practically are inclined to doubt it, that such buildings as are now in use as barracks for British troops throughout India *cannot* be properly ventilated except by artificial means, and that no amount of opening of doors and windows will compensate for the

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the placing of doors and windows, etc., alluded to above is excellently illustrated in almost any barrack and military or civil hospital. Even where some well-informed and thoughtful man points out the shortcomings and defects he will be quietly ignored by some more potent individual who thinks sanitation "all fudge and nonsense."

* *op. cit.*

† "There can be but one opinion regarding the advantages, in a sanitary point of view, and, I believe, in regard to economy as well, of the location of troops or other large bodies of men in small parties in separate apartments. Some of the new, double-storied, one-company barracks, lately erected in India, are said to have cost upwards of 170,000 rupees each. Now, a very excellent, substantial house, containing four or five good rooms, each room affording ample accommodation for four men, could be erected for 8,000 rupees; six such houses could accommodate a company, including non commisioned officers; and four more similar houses on a slightly modified plan, for married men, would make a total of ten houses for each company, at say an average cost of 80,000 rupees, being less than one-half the sum which is said to have been expended on the immense piles of buildings alluded to, which will certainly have their turn of unhealthiness like their predecessors." [A true prophesy]. "When I speak of a house costing 8,000 rupees I mean one of a permanent description, built as substantially as the barracks in question." [This was thirty years ago; the cost of such a bungalow would be greater now, but so would the cost of the barracks]. Stewart Clark, *op. cit.*, p. 128.

want of this.* Elaborately-calculated inlets and outlets are all very well in a country like England where ventilation by circulation is constantly possible, but in India, as before stated, such is not the case, and the evils of deficient ventilation become many times accentuated in a barrack room where the useful cubic space† per man and the superficial area are generally far below the proper amount. In addition, it must be remembered that the barrack rooms are continuously occupied by a certain proportion of their inmates, night and day, a very different condition of things to the rooms of an ordinary house which are only inhabited continuously for a few hours.‡

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* This defect is probably not so marked at places like Colaba and Fort St. George, which are constantly exposed to the sea-breeze; but in mofussil stations, where the choice for months lies between no ventilation or the free ingress of a burning wind laden with dust, varied with a chilling breeze laden with moisture, the want of systematic ventilation is evident to the most casual observer. Unfortunately, on this point also, there are, as usual, no reliable scientific observations available. "The standard barrack plan is, I think, rather a mistake, because *no one plan of barrack or bungalow is suited to every varying climate of India.* The climate demands modifications which have not been sufficiently considered, or at least authorised. *Barrack rooms should be so constructed as to admit of every man being partially screened from his neighbour.* Over-ventilation is a most fertile cause of chill, and chill is a most fertile cause of disease. Over-ventilation should be guarded against as much as under-ventilation. Ventilation in barracks is often excessive. If the doors and windows are open the men sleep in a draught, if shut they breathe foul air. There should be small windows above each bed, and so protected that while the most thorough current is secured above, draught on to the bed is impossible. In some few stations better bungalows for officers have been provided, but *much remains to be done under this head.*" Sir W. Moore, *op. cit.* The italics are mine. Regarding the remarks about 'over-ventilation,' it will be evident from what has been said in various parts of chapters I and V that the proper term is rather 'defective *methods* of ventilation.' So long as reliance is placed on purely natural means of ventilation and no proper attempt made to adopt some simple artificial method of regulating the amount and direction of the fresh air supply, so long will barracks and other Indian buildings be 'over-ventilated' at one moment and 'under-ventilated' at the next.

† *v.* p. 32.

‡ The subject of barrack construction and ventilation is briefly considered in its main points in Parkes-Notter, *op. cit.*, p. 517, *et seq.* "In India vast and extensive palaces have been reared in many stations, which testify at any rate to the anxiety of the Government to house their soldiers properly. Some of these great barracks, as at Allahabad, have not given satisfaction and have been found as hot or even hotter than the old barracks"—apparently from omitting to shadow all main walls with a verandah, and from insufficiency or omission of openings in the roofs and verandahs. The general principles of the proposed plans for barracks submitted by the Indian Sanitary Commission were undoubtedly good :—

There are many other points regarding the hygiene of barracks and barrack life, the consideration of which must be postponed till a future chapter.* It may be noted, however, that a soldier occupies an intermediate position, hygienically speaking, between ordinary civilians and the occupants of asylums and prisons, approaching most nearly to the condition of life of boys at a boarding school. He is to a certain extent looked after by the Government in whose charge he is with regard to his work, dwelling place and general surroundings: on the other hand he is free to move about, eat and drink, etc., where he pleases, within certain limits, so that although neither insane nor a criminal he is exposed to many risks of disease from which these latter classes, by their rigid confinement, are freed. Under these circumstances, the only effective rule, as in the case of school boys, is the rule of kindness and a good example, by which the soldier may be taught to respect himself and the uniform he should be proud to wear.

SCHOOLS.

The hygiene of schools has only begun to attract general attention in England and America of late years; in India the subject is still in its infancy. This is the more to be regretted when one considers what an extremely important influence such institutions have on the future men and women of a country, who in their turn will become the parents of the succeeding generation.

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number of men under one roof to be 40—50 (half company barracks), except under exceptional circumstances [which should only refer to barracks in actual forts, etc.]; number of men in one room to be 16—20 and not to exceed 24; barracks to be two-storied in the plains and one or two-storied in the hills; single verandahs of 10—12 feet to surround these rooms; only 2 rows of beds in the dormitories, with beds 9 inches from the walls and a door or window for each two beds; closets and night urinals to be at extreme end of the verandah, leaving a space between them and the dormitory. 'Broadside on to the prevalent wind, and disposal *en échelon*, as now adopted in India, is obviously the proper plan' for arrangement of the buildings. But with all this the fact remains that many barracks do not comply with the above proposals, and that even when they do there are very many defective points in regard to construction and above all as concerns ventilation, which latter *cannot* be combined with coolness and freedom from injurious draughts so long as reliance is placed on natural means alone.

* *v.* Part IV.

Schools are divisible into two great classes, *viz.*: boarding schools, at which the scholars live, and day schools, to which the scholars go for so many hours daily, returning home at night. The subject of residential or boarding schools hardly concerns us here, for in India they are very limited in number and are principally Government institutions at which considerable attention is paid to the hygiene of the inmates.* Of more pressing importance is the condition of the scholars and their surroundings in the ordinary day schools and colleges scattered throughout the empire. It may be stated at once that by far the greater number of Indian schools are conducted in dwellings not originally intended to be used as such or else built entirely with a view to crowding as many persons as possible into a given space. Into the countless sanitary defects common to the large majority of these buildings it is impossible to go in detail here; all that can be attempted is to indicate some of the points to which special attention should be directed.

Ventilation.—As in other buildings, the first point requiring careful consideration is the ventilation. In the smallest native schools this problem is frequently solved by the teaching being done entirely in the verandah of the house wherein the master resides, and as the children taught are limited in number they probably each receive a fair allowance of air.† It is otherwise, however, when they are crowded into a small, hot building with no special provision for ventilation and the superficial area per head limited to the space actually occupied by each child. Remember that in children at their lessons there is a double reason for a plentiful supply of pure air; firstly, because they are young and their bodies are growing actively; secondly, because

* In these institutions there is generally a resident apothecary and a visiting medical officer. Upon the amount of personal interest taken and vigilance exercised by these officials depends chiefly the hygienic condition of the school and its inmates.

† Not necessarily pure, fresh air, however, for these schools are usually situated in crowded and dusty bazaars where the external ventilation is as bad as can be. Still, it is the same atmosphere as that in which their dwellings are situated, and can only be remedied by a general improvement in the bazaars themselves.

they are engaged in study, which means the expenditure of nervous energy and implies the necessity for clear-headedness. It is absolutely essential, then, that they be supplied with the proper amount of fresh air, cubic space and superficial area.* There is yet one other reason for abundant ventilation and that is the ease and rapidity with which the numerous contagious disorders of childhood,—measles, whooping-cough, diphtheria, etc.,—spread from one to the other. The testimony of all authorities on this subject amply confirms the above statement and, as a result, it has become customary, on the occurrence of an outbreak of contagious disease, to at once close even the best managed schools, till such time as the danger of infection shall have passed away.

Light.—The next important point is the amount and direction of the light supplied to the scholars.† If, from any reason, the amount of light is too small, the eyes, by constant straining to decipher words or figures, become seriously affected, and contrariwise, if the glare is too great, the vision will certainly be injured in time. The former is probably the more common evil in this country and systematic inquiry would doubtless demonstrate the fact that the rising generation of Indian students contains a very high percentage of myopic subjects. The light should fall on the left hand side of the pupils, entering through windows beginning from four to six feet from the ground, rising almost to the ceiling, and so protected with sunshades as to prevent the passage of direct sunlight.

When a child is very young and learning to read, it has to *spell out* each word, letter by letter, the labour of doing so being increased or diminished by the smallness or largeness of the type. For very young children the size known as *pica* type is the best: when they are older and begin to take in the words at a glance, their books may be printed in *small pica*, the type in which this book is printed.

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* *v.* Chap. I, pp. 23, 33 and practical rules at the end of this section.
† *v.* Rules at the end of this section.

Desks and Seats.—The old-fashioned custom, which still obtains largely, of having rows of 'forms' or plain seats without backs for children to sit upon, and high desks in front for supporting their books, etc., is a distinctly injurious one and should be abandoned in every school. The spartan idea that a boy or girl should be made supremely uncomfortable when young is happily dying out and its place taken by the more rational and humane belief that they should be made healthy. When seats with backs to them first began to replace forms, it was thought sufficient if the backs were made almost, if not quite vertical. This is a grave mistake; the back of the seat should be so curved as to adapt it to the spinal column, and the seat itself should be ten inches wide at least and about the height of the child's knee. The desk should be sloping, not horizontal, and its edge about the height of the elbow. When used for reading the edge should be in vertical line with the edge of the seat; when required for writing it should be slightly pushed back. To obtain this movement a simple horizontal adjustment of either seat or desk is necessary. The best authorities are of opinion that each scholar should have a separate desk and seat according to stature and size. The following table* was prepared as a result of experiments made in this direction and may be taken as a guide. It shows that eight different sizes are required for a school where the pupils range from three to five feet four inches in height.

Height of Pupils.	Height of Table.	Height of Seat.	Height of back of Seat.
Feet.	Inches.	Inches.	Inches.
3·0 to 3·3	13·5	7·5	9·8
3·3 to 3·6	14·7	8·5	10·8
3·6 to 3·9	15·8	9·5	11·9
3·9 to 4·2	17·0	10·3	12·9
4·2 to 4·5	18·1	11·2	14·0
4·5 to 4·8	19·2	12·2	15·0
4·8 to 5·1	20·4	13·1	16·1
5·1 to 5·4	21·6	14·1	17·2

* By Dr. Guillaume, quoted by W. Blyth, Dict. of Hygiene, p. 512.

It is of great importance, then, that strict attention be paid to providing suitable seats for children, both for the sake of rendering them comfortable and thereby more fit for work, and to prevent injury being done to their spines before complete ossification has taken place.*

Of the many other matters in school hygiene for which constant and specially trained supervision is necessary, no further mention can be made here save to indicate the more important. (1) All schools should be inspected regularly by trained sanitary officers.† Routine inspections by ordinary medical officers already overburdened with work, are, with rare exceptions, useless. (2) The hours of work and play must be most carefully apportioned and strict adherence to these hours by the teacher insisted upon. (3) The latrine accommodation must be suitable, sufficient and inspected daily. (4) A suitable piece of land immediately adjoining the school should be set apart for the exclusive use of the children as a play-ground. (5) The children should be encouraged during recreation time to indulge in games and pastimes, and all solitary loafing prevented as much as possible.‡ On the other hand, if gymnastic exercises and other athletic sports are insisted upon, the greatest care must be taken that no child is made to unduly exert itself. The course should be occasionally, say once a month, watched by a medical officer. (6) The whole school should be medically inspected by a subordinate medical officer once a month with a view to the detection of disease, especially contagious skin diseases, ophthalmia, etc.

These points are not trivial and of small account: on the contrary, they are of the highest importance, and under

* "There is a general impression that deformities of the vertebral column, formerly rare, are now on the increase; this is most certainly due, in a measure, to ill-constructed seats." Dr. Blyth, *op. cit. supra.*

† Who may be officers of the Educational Department, if any can be found with the necessary aptitude and training. In addition there should be an annual inspection, at an unfixed period, by a capable medico-sanitary official.

‡ Note that the lower the social position of the pupils, the harder it is to induce them to take kindly to games and sports.

no circumstances are kindness and consideration better repaid or more worth expending than in the proper care of children. The good effected, as stated before, does not end with their schooldays but continues throughout their lives and makes them valuable citizens and the parents of healthy offspring. "The necessity for ensuring the best hygienic conditions in buildings for children, of whatever social class, is more than ever important now that the strain upon the child is so much greater than formerly, and consequently everything that may conduce to counteract this strain and pressure of education is indispensable, whether it concern the internal or external arrangements."*

The following excellent rules,† comprising the essentials for schools with regard to lighting and ventilation, are worthy of careful attention and consideration.

LIGHTING.

"1. Good lighting of school or class-rooms depends upon (1) sufficiency of light, (2) distribution and employment of the light to the best advantage.

2. As regards sufficiency, the general rule is that apertures for light should be about equal to $\frac{1}{5}$th of the floor area of the room to be lighted. A room 20 × 20 feet requires about 80 square feet of light. Another calculation is that there should be 200 square inches of light for each pupil, but something depends upon the situation and aspect of the building, and it is generally easy to see whether a room is sufficiently lighted or not.

3. As regards using the light, the thing to be kept in view is the avoidance of all strain or tension on the eyes of the children. Strain is caused

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* S. and M., *op. cit.*, p. 702.

† Drawn up by Mr. T. B. Kirkham, Educational Inspector, Central Division, Bombay—and issued by the Department of Education for that presidency.

either by an excess or by a deficiency of light. Working in shadow and working in glare are equally injurious. The seats should be so arranged that the largest possible number of children may work in light *falling from the left side and as far as possible from above.* Side light from the right is next best, whilst light from behind is bad, because the body throws a shadow on the work. The worst light of all is that from the front falling on the faces of the children. This is most injurious, and should always be avoided. Where desks are used, the window sills should be higher than the desks, as light from below is confusing and fatiguing. The windows should be fitted with shutters to exclude the direct rays of the sun, when necessary. It may be added that in night schools the artificial light employed should be steady and not flickering. Colour-washed walls are preferable to whitewashed, which are apt to cause glare. French grey, light stone colour, or the light blue so easily procurable in these parts, distributes the light in the room much better than white.

VENTILATION.

4. Good ventilation, in like manner, resolves itself into (1) sufficiency of air or cubic space for the number of children to be accommodated, and (2) arrangements for changing the air as fast as it is used up.*

5. As regards sufficiency, sanitary authorities claim a space of 200 cubic feet or upwards for each pupil, but in India, where the doors and windows are habitually kept open, measurement of the floor-space is sufficient for all practical pur-

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* *v.* Chap. I.

poses.* Assuming that the rooms are at least 10 or 12 feet high (14 feet is a better height), a minimum floor space of 10 square feet should be allowed for each child in attendance in a primary school, whilst 15 square feet and upwards should be allowed in secondary schools. For youths and big boys, 20 to 25 square feet per pupil is not too much.

6. With regard to the changing of the vitiated air, the thing to secure is *circulation without draughts*. The prevailing winds should be admitted and the impure air should be allowed to escape, whilst at the same time the breeze should not be allowed to play directly upon the bodies of the children.

7. From the above it will be apparent that the best windows for school and class-rooms, both for light and ventilation, are those which have deep window sills, say 4½ feet high, and which go up high towards the ceiling. With such windows the light falls from above, and the children are at the same time protected from

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* The remarks here on ventilation, cubic space, etc., can only be considered to have reference to making the best of the existing state of things. A floor space of 10 square feet and a cubic space of 120 feet in a room twelve feet high is certainly too little. But little more than half of this will be 'useful' cubic space (*v.* pp. 32-3 and 269), and to give a sufficient amount of fresh air (2,600 cubic feet per hour) the air must be totally changed more than twenty times. During certain seasons of the year this may be possible without direct draught, but at other times when there is no wind, and ventilation by circulation is at a standstill, it is practically certain that in a room 20 × 20 × 12 (= 4,800 cubic feet and 400 square feet), supposed, therefore, to accommodate about 40 children (at 10 square feet superficial area each), the necessary amount of fresh air, 104,000 cubic feet (at 2,600 cubic feet each), would not pass through the class-room, far less be utilised. A *larger* cubic space than in England is essential in a tropical climate, not a smaller, (*v.* p. 33). No plan can be really effective which does not make provision for the artificial supply of a *definite* amount of fresh air whenever thorough perflation is impossible, either from want of wind or from the trying nature of the wind. Carnelly, Haldane and Anderson in their well known series of practical experiments (*v.* Phil. Trans., 1887), have conclusively shown that even in Great Britain, where ventilation by circulation is in constant action, schools which are ventilated by mechanical means have much purer air than those ventilated naturally.

draughts. Small lattice window panes are objectionable. In ordinary cases, iron bars and wooden shutters on hinges answer best. Windows not protected by verandahs should have 'hoods,' so that they need not be closed for sun or rain. Perforated zinc has in many cases been found to prevent sufficient change of air and should only be adopted after careful trial. It need hardly be said that every class-room should have all its doors and windows thrown open, and be *thoroughly flushed with fresh air during every recess* and on every other available opportunity. In all new buildings, and wherever it can be introduced in old ones, ridge ventilation should be adopted."

8.* * * *

SHOPS, OFFICES, ETC.

The same defects as have been noticed in the case of schools, barracks, houses and other buildings will be found on inspection to exist in connection with shops, offices and public buildings of various sorts, *e.g.*, post offices, courts, theatres, etc.

Latrines.—One of the commonest and most serious is the want of proper latrine accommodation. It is not perhaps in this country an evil of such magnitude as in Great Britain and other European countries, on account of the general absence of a water-carriage system for the removal of excreta.† Still, it is essential that in any building wherein a large number of persons are employed there should be a sufficient amount of latrine accommodation afforded for all purposes, so as to avoid crowding, indecency and the creation of a nuisance. There must be separate latrines for both sexes, each containing a suffi-

* Has reference to the examination of the ventilation of a room. *v. ante*, pp. 42-3.

† Note, once more, that a badly managed water-closet, *i.e.*, one originally defective and allowed to fall into disrepair, is a literal death-trap.

cient number of partitioned closets, provided with dry earth, etc., well ventilated by perflation, cut off from the main building by cross-ventilation, and kept in a state of thorough cleanliness.*

Ventilation.—This likewise is often lamentably deficient, especially in mercantile offices and large Government offices occupied by the under clerks, and regular inspection of the same, accompanied with power to compel the application of remedies, is urgently required.† By far the worst, however, in this respect, as in others, are the Courts of Justice throughout India,‡ with but few exceptions. There is more need for unlimited fresh air in these buildings than in any others and yet the means of ventilation are frequently, to all intents and purposes, *nil !* "Owing to the noise that an Indian crowd *will* make in the corridors and outside of a court, the doors have frequently to be shut, in order that the business of the court may be heard. Crowds in any court usually contain a large unwashed element, and a court house soon acquires a kind of menagerie smell, familiar to all who frequent them, which seems to impregnate the walls and remain even when the building is empty."§ * * * "The administration of justice for many hours together, day after day, in a very foul atmosphere is not only bad for the highly educated and highly paid men who preside in the courts, but bad also for the work they do. It is impossible to work long in a badly ventilated court without suffering an amount of bodily and mental fatigue, which must militate against good work, and which is all the more to be deplored as it is quite unnecessary. Poisoning, by means of twice or thrice breathed air, is a slow process, involving slow

* If necessary, a *very small* deduction may be made from the pay of the *employées*, monthly or weekly, to ensure a sufficient staff of sweepers, etc.

† There is no doubt that ample fresh air, with coolness of the same, if merchants and others would only believe it, would enable them to get far better work from themselves, their assistants and their clerks.

‡ As in England also.

§ In fact the loathsome smell of organic matter that formerly characterised prisons and hospitals everywhere, and which is now almost abolished in civilised countries, save in the dwellings of the poorest classes.

deterioration which may continue for years, with intervals of change and recuperation, but the average intellectual vigour of any man in such circumstances must be a good deal under par."*

Cooling.—The usual methods for obtaining coolness in Indian buildings are to build walls of enormous thickness, to make the verandahs low and the windows as small as may be, and to use punkahs and *khas-khas tatties.* From what has been said in this and preceding chapters (I and III), it will be evident that these are very partial remedies and have serious drawbacks as a set-off. The only proper means is to *combine cooling with ventilation,* and that this will some day become general there is no doubt. Meanwhile, where bricks or country tiles are used as flooring, a good deal may be done by availing oneself of the cooling effect of evaporation, without the disadvantage of using an organic material such as *khas-khas.* The floor should be carefully swept early in the morning and thereafter water liberally poured on by a *bhisti* or other servant. With the doors or windows on the shady side kept open and punkahs swinging, the temperature may be materially lowered throughout the day, without the creation of the chilling draught from a *khas-khas* screen.†

Hours of Work.—It is principally the assistants in shops who suffer from effects of over-work. The general conditions under which they are obliged to pass their long day—a hot, stuffy shop, constant worry, continual standing, insufficient meal-times, etc.—all tend to undermine their

* Wallace, *op. cit.*, pp. 224-5. No better example could be given than the present Blacktown police court at Madras, relatively, a most expensive building. It is simply a dark, hot and excessively foul cellar as regards the lower storey, and but little better above. Doubtless any intelligent reader can supply examples for himself.

† This has been known for a long time to some, but is not nearly sufficiently taken advantage of. Suitable modifications of this plan might be adopted for houses, etc. By these means Wallace, (*op. cit.*, p. 190) obtained a reduction of 15° F., in the shade temperature between the verandah and office, and an increase of 31 per cent. of humidity at Cawnpore at 2 P.M. on a July day. Of course where the air already contains a high percentage of moisture, so great a reduction would be impossible.

health and render them liable to break down at any time. Eight hours, including one hour for meals, is the limit during which they should be called upon to serve, instead of which they are commonly made to stay from 8 A.M. till 6-30 or 7 P.M. They should also have seats provided for them and be allowed to use them when not serving. For lunch or dinner one hour is the shortest time allowable, whereas the heads of some establishments consider themselves indulgent if they give them a short half hour.

Housing.—This subject also demands attention by reason of the fact that proper houses for European shop assistants are not available to anything like the extent required. The humane owner of some large business, whereat many European assistants are employed, might well set a good example by building two sets of several small bungalows each, after the type of 'subalterns' quarters' at certain stations or 'bachelors' quarters' at some hotels, wherein the employées might reside, having common dining and recreation rooms, tennis courts, etc., and proper sleeping accommodation. The rent charged need be very little, if any, higher than that now paid by the assistants, whilst the gain to their health and consequent saving to the establishment would soon be demonstrated.*

Of many other buildings such as hotels, theatres, factories, etc., the defects in their construction and sanitation, and the proposed remedies, it is impossible to write here. In all cases the general principles are the same, and the intelligent sanitary officer will be able to detect the weak points and to advise as to the remedy required.

* This may have been done already, but I do not know of a case.

CHAPTER VI.

CLIMATE AND METEOROLOGY.

THE term climate, derived from the Greek word *Klima*, a slope, was formerly confined to astronomical or mathematical geography and had reference to the portion of the earth's surface included between two lines parallel to the equator and measured by the length of time during which the sun appears there during the summer solstice, *i.e.*, by the sun's inclination. The space between the equator and the pole was divided into half hour climates, in which the length of each day increased by half an hour. This unequal division of the hemisphere is now replaced by a division of the interval between the equator and the poles into ninety degrees, which constitute what are called degrees of latitude, and the word climate has received a more extended application.*

From the point of view of a sanitarian, the climate of a place may be defined as *the sum of the local atmospheric and physical conditions in their relationship to animal and vegetable life.* From climate, the expression 'weather' must be distinguished. By the former is meant the average condition of heat and cold, damp and dryness, and the like, characteristic of a place or country, in so far as they vary regularly with the succession of the seasons. The latter has reference to the apparently irregular, though not always minor atmospheric changes that take place from day to day.†

For our present purpose, it is necessary to study the climates of different places and their influence upon the health of the inhabitants; the various climatic factors and

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* *v.* Article, 'Climate,' by J. H. Bennet, Quain's Dict. Med., vol. I, p. 262.
† *v.* Blandford, Climates and Weather of India, p. 197.

their effects being considered, (1) individually, (2) collectively.* In addition to this which constitutes the science of Climatology, the means by which these climatic factors are estimated and expressed, in other words, the science of Meteorology,† must receive attention.

Climate as modified by the physical conditions of any place has been already partially considered‡, and the subject will be again referred to later. There remain, therefore, to be inquired into, as regards causation, significance, etc., the varying conditions of the atmosphere surrounding the earth, which exercise so important an influence on all organisms from the highest to the lowest.

THE ATMOSPHERE.

Before proceeding to examine in detail the various atmospheric conditions, a few words about the atmosphere itself are necessary. Of its composition sufficient has already been said.§ As regards the relationship of the atmosphere to the earth on which we live it may reasonably be compared to the mass of water superincumbent on animals living at the bottom of the sea, so that in like manner human beings may be said to live at the bottom of a "shoreless ocean of invisible fluid, to the surface of which they are powerless to rise." The atmospheric envelope probably extends more than two hundred miles from the earth's surface, but by reason of its compressibility nearly three-quarters of the total amount of air lies between sea-level and the tops of the highest mountains.‖ In addition, it is certain that an enormous amount

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* The weather, of course, is of importance likewise, but more especially to sailors and engineers. To Sanitary Engineers, an intimate knowledge of the climates and weathers of India is most essential. The few facts already known and studied in this relation will be found in Blandford (*op. cit. supra*) and Wallace (*op. cit.*)

† The science of Meteorology serves two chief uses, *viz.*, (1) the obtaining of *data*, at daily or other fixed intervals from various meteorological stations whereby the probable weather may be foretold,—'Weather Forecasts', (2) the gradual accumulation of *data* relating to each station, upon which a knowledge of the climate of that particular place may be founded.

‡ *v.* p. 111. § *v.* Chap. I.

‖ *v.* Discussion in 'Realm of Nature,' H. R. Mill, p. 100.

of air is contained dissolved in the water surrounding the earth (hydrosphere), and is present also in the pores of the soil as ground air, the gases being present, however, in varying relative proportions.*

As regards the atmosphere itself, its composition is wonderfully constant, such constancy being partly due to the diffusion of gases,—the particles of which pass each other freely, without interfering, like crowds moving in different directions across a market place,—and partly to the gaseous interchange between animal and vegetable organisms.† The variations that are constantly occurring in the degrees of atmospheric humidity and pressure will be considered later.

Elements of Climate.—Understanding then, as far as may be, the nature of the atmospheric envelope and its composition, we are in a position to take up, one by one, the consideration of the various conditions or climatic elements of which the atmosphere is the agent or medium as it were.‡ These are (1) the Temperature (and Diathermancy); (2) the Humidity; (3) the Atmospheric Pressure (or Density); (4) the Circulation (or Movements) of the Air; (5) Light and Transparency; (6) Electrical States of the Atmosphere; (7) Atmospheric Dust. In this chapter each of these elements of climate will be considered with reference to the circumstances which produce or modify it, its relation to health and disease, the instruments and methods of observation which it requires, and its special manifestations in the climate of India.§

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* *v.* pp. 66 and 118.

† *v.* Part II., Chap. VII., introductory remarks.

‡ These conditions, though conveniently considered as atmospheric, are not solely so, by any means, and are largely modified and influenced by the configuration of the land, nature of the soil, relative amounts of land and water, etc.

§ The science of meteorology is now so advanced and requires such accuracy in the methods of observation that it is impossible to do more than give an outline of its principles and practice in this manual. Those who wish to pursue the subject further or to undertake meteorological observations must carefully peruse the works of Blandford and other Indian meteorologists and pay strict attention to the instructions given therein.

TEMPERATURE.

Temperature* is one of the most important of the elements of climate, both directly of itself, and indirectly, since the radiant energy derived from the sun,† in its passage through the air to the earth's surface, is the original cause of all atmospheric changes. It is necessary to distinguish carefully between radiant or sun heat, and air or shade heat. At great altitudes, where the air is very pure and dry, the sun's rays have but a very slight warming effect on the air as they pass through it, but great power of directly heating the bodies of animals and other solid objects upon which they fall.‡ The gaseous particles, in other words, are able only very slightly to absorb the heat from the sun's rays and are therefore called *diathermic* or transcalent.

At lower levels, however, the air is full of water vapour and dust particles, and these, during the day time, absorb the radiant energy of the sun's rays and heat the surrounding air. In addition, the surface of the earth absorbs a considerable quantity of the solar radiant energy which it in turn radiates back to and thus warms the air. It is important to notice also that a considerable amount of heat is temporarily retained, as it were, near the earth's surface and helps to raise the temperature of the air. This was formerly believed to be due to the assumed fact that the water vapour was much less diathermic to the invisible heat rays radiated back from earth than to the direct luminous solar rays. It is now pretty certain that the

* "When a substance grows hot, it increases in energy, and is said to *rise in temperature*. The word *temperature* has not the same meaning as *heat*, but corresponds exactly to *hotness*. Temperature is a quality : heat is a quantity." Ramsay, Elementary Systematic Chemistry, p. 5. As a matter of fact, the term heat is often used to express the quality of hotness ; the sense being evident from the context.

† The additional heat derived from the moon, stars and interior of the earth, is so small in amount that it may be disregarded here.

‡ At Leh, in Northern India, 11,500 feet above sea-level, Dr. Cayley raised water to the boiling point by exposing it in a blackened bottle (placed inside another bottle to protect it from cooling by the wind) to the direct rays of the sun (*cf.* black-bulb vacuum thermometer, p. 298).

chief absorbents of radiated heat are condensed vapour and the dust particles of the atmosphere. Hence on clear evenings, when the amount of condensed moisture in the atmosphere is small, the temperature falls rapidly after sunset and *vice versâ*. The suspended dust probably plays an important part in the diurnal heating of the lower atmosphere which gives rise to the hot winds of April and May.*

There is then to be distinguished, practically, the influence produced by the direct heat of the sun (sun heat) and that produced by the warming of the air (shade heat) through absorption of heat by the water vapour and dust particles in the atmosphere. The shade heat, itself, is partly derived from radiant solar energy directly and partly from heat radiated back from the earth's surface by land and water. Of these two,—sun heat and shade heat,—the shade heat or temperature of the *air* at any place is by far the more important and must be further considered.

Shade Heat.—The temperature at any place depends primarily on the *quantity of solar heat absorbed and radiated back* by the earth's surface and by the amount of moisture and dust particles present in the atmosphere. Certain circumstances modify this quantity ; of which the principal are :—*latitude ; elevation ; quantitative relation of land and water ; character of the surface ; existence of currents, either of air or of water ;* and *rainfall.*

Between the tropics the sun is always vertical somewhere ; and nowhere do the solar rays strike the surface at noon with any considerable degree of obliquity.† In the Low Latitudes of the torrid zone, therefore, the greatest quantity of solar heat is received, and the lower the latitude, (if other things be equal), the higher will be the mean temperature. Owing to disturbing causes, however, the fall in temperature as the latitude increases is not regular.

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* *v.* Blandford.

† *v.* Explanation and diagram, Realm of Nature, p. 82.

Elevation Above Sea-Level reduces temperature. The air being chiefly heated, not by the solar rays which pass through it but by radiation from land or water, the strata nearest to the general surface must be the warmest and heat will diminish in proportion to height. A hill or range of hills, therefore, will be cooler than the plain from which they rise. Again, the greater the elevation, the less the mass of heat-absorbing matter and the more rapid its radiation into space. At the greater heights, also, there will probably be less atmospheric moisture and dust to absorb and radiate the heat proceeding both from the sun and by radiation from the earth. The fall in temperature due to elevation is chiefly due, however, to *dynamical cooling*, as it is called. Heated air currents as they rise are naturally subjected to decreasing pressure and consequently (by Boyle's law) expand considerably. The act of expansion, being work done against gravity, causes the consumption of heat with a consequent fall in the temperature = 1° F. for every 180 feet of ascent when the air is unsaturated. Conversely, cold air carried downwards from a great height towards the earth's surface, is continually subjected to an increasing pressure and its volume diminished. The work so done on the air by gravity is changed into heat, whereby the temperature of the air is raised 1° F. for every 180 feet of descent.*

The Relative Amounts of Land and Water influence temperature to a powerful degree; the more the latter preponderates the lower will be the mean temperature and the more equable the climate. Land absorbs, and therefore radiates, heat more readily than water. Its specific heat, also, being very much lower than that of water, its tem-

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* Practically, however, the decrease of temperature, is found to be 1° F. for every 270 feet of ascent. "Thus, whatever the temperature may be at sea-level, there is a certain height where the air has an average temperature of 32° F., no matter how much sun heat passes through; and snow which falls above that height does not melt. This limit is termed the *snow line*. It is sea level in the extreme arctic regions, about 5,000 feet at latitude 62° in Norway, about 9,000 feet in latitude 46° in Switzerland, and above 16,000 feet at the equator." H. R. Mill, *op. cit.*

perature rises higher in a given time of exposure to solar heat; so that while a thermometer placed on the ground in a hot country may rise to 160° F., (or even to 237° F. if protected from air currents), the surface temperature of water rarely exceeds 80°—90° F.*; and the air immediately above it will be cooler still by from two to five degrees. Heating during the day and cooling during the night being, then, more rapid processes in the case of land than in that of water *the diurnal and annual ranges of temperature will be less in insular and coast positions than in the interior of continents.*†

The nature of the Soil and its effects upon temperature have been already considered.‡ Some soils absorb heat and give it out more abundantly than others. Bare surfaces will heat the air more, and more quickly than those clothed with vegetation. Evaporation from water or from wet surfaces, like marshes or the banks of tidal streams, cools the air. The shelter of hills or high rocks, may lower the temperature of certain spots by diminishing the duration of exposure to the solar rays or by keeping off a chilling wind.§

Currents, aerial or oceanic, are well known to modify temperature. The hot land-wind, the cool sea-breeze, the

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* *Enclosed* tropical seas have the highest temperature of any water surfaces in the world. In the Red Sea readings of from 90°–100° F. have been reported, but the hot surface water in the tropical zone is merely a film covering a vast depth of cold water.

† *v. post.* under Climates.

‡ *v.* Chap. III.

§ The local influence on the temperature exercised by land and water respectively, is often very noticeable early in the night in India. When marching along a road in hot weather and approaching a large tank or other sheet of water the air feels much colder for some minutes before arrival at the water and continues so till it is left behind. Again, when approaching one of those bare, rocky hills, so common in central and southern India, the temperature of the air is considerably raised, so that the feeling is like that of entering an oven. In the one case the solar heat has been absorbed slowly and is being slowly radiated back at night, in the other, the large quantity of heat absorbed during the day is being rapidly radiated back to the air. In addition, in the latter case, the large mass from which heat is radiating must be taken into consideration, and in the former, the cooling effect on the air due to the evaporation going on from the water surface.

trade-winds blowing from polar towards equatorial regions, are familiar instances of the former; the gulf-stream of the latter. Winds may act indirectly also upon temperature, by bringing up clouds which either fall in rain or absorb heat, solar and terrestrial.

In tropical countries Rain has a marked influence in lowering the temperature, partly on account of the circumstance that since it falls from higher and cooler regions it is actually at a lower temperature than the air at the earth's surface, and partly because of the cooling due to subsequent evaporation. It should, however, be noted that the increased dampness of the air after a shower largely neutralizes the benefits of the lowered temperature.

In considering the effects produced on the human organism by alterations of temperature, there require to be noticed; (1) the effect of a *sudden change* from a low to a high temperature and *vice versâ*; (2) the effect of a *gradual lowering* of the temperature; and (3) the effect of a *gradual raising* of the temperature.

Effects of sudden changes in temperature.—These are apt to be most trying and may indeed have a fatal effect on persons who are in any way debilitated or sick already. There are two occasions in Indian life when this danger is especially prominent, *viz.*, at the setting in of the 'rains' after a lengthy period of hot, dry weather, and on going up to a hill station at an elevation of 5,000—8,000 feet.* In either case there is great risk of sudden congestion of the visceral organs. In a healthy person the free action of the skin, which is his safeguard in a high temperature, is checked, but its place is taken by greatly increased renal secretion and, in some cases, by diarrhœa for several days in addition. On the other hand, persons newly arrived in the tropics from colder climates run a great risk also, unless very careful. If their skin acts freely and they do not expose themselves too much to the sun there is not much fear of harm; but if at all careless, so that their

* A journey of 3—5 hours duration only by pony *tonga dâk*.

perspiration receives a 'check' as it is called, the probability is a violent attack of congestion of the liver or worse. In either case, a healthy person will be perfectly safe if reasonable precautions are taken as to food, its quantity and quality, clothing, exposure to the sun or to chilling winds, etc., etc. For those in any way out of health or weakened by long residence in a tropical climate, the greatest care is necessary, and their change to a lower or higher temperature should be as gradual as possible.*

Effects of Cold.—To healthy adults a low temperature is certainly not detrimental and is probably beneficial. Humid cold, where the air contains a high percentage of moisture, is very trying and, if the temperature is very low, may be fatal. If, however, the air is very dry, a most extraordinary degree of cold (as of heat) can be borne, such as −70° F. or 102° below freezing point. Prolonged exposure to great cold means complete physiological contraction of the arterioles and capillaries, with consequent interference with the circulation of the blood, resulting in death commencing at the extremities, *i.e.*, in the most distant and dependent parts. In addition, from the same reason probably, either extreme drowsiness with diminished sensibility comes on or, in some cases, delirium; death occurring from coma, rarely from syncope or asphyxia.

Effects of Heat.—A slight rise of the bodily temperature (from 0°·5 to ·1° F.) is one effect of a heightened atmospheric temperature and is observed, temporarily, in transition from a temperate to a hot climate. Taking the normal temperature of the body in England at 98°·30 F. it was found to be 98°·66 within the tropics, and 99°·02 at the equator, the thermometer standing at 84°. There seems to be a slight but regular increase of bodily, proportional to rise of aerial, temperature, each degree of the latter corresponding to 0°·05 of the former. This increase is observ-

* For further information on this important subject, *v.* Chevers, Diseases of India, p. 9, *et seq.* and references therein given.

able in new arrivals at the tropics; it is not quite certain whether it is permanent or not. It occurs even when external and internal heat, on the one hand, and radiation from the body, evaporation from skin and lungs, and movement of air, on the other, maintain their normal correlation, and is not to be regarded as pathological. When, however, excessive humidity interferes with free evaporation, the temperature of the body rises and may increase to a dangerous extent. In the well-known experiments* in which the effects of exposure to a heated atmosphere in ovens were tried it was found that a temperature of 260° F. could be borne without injury or serious discomfort and with a rise of but 2°·5 degrees of bodily heat, provided the air was dry and free evaporation from the skin and lungs possible; but that in a moist atmosphere the temperature increased by 8°. The effects of intertropical heat, then, in raising the temperature of the blood are partly constant and partly dependent upon atmospheric humidity.

The function of Respiration is less actively performed in a hot than in a temperate climate. The number of respirations is diminished, and about 20 *per cent.* less carbon and water are eliminated by the lungs. Not only is less air by 18 *per cent.* respired in a given time but that which is taken into the lungs, being rarified by heat, contains less oxygen in a given volume than in cooler places. Thus it is estimated that 9 *per cent.* less oxygen is inspired at 80° F. than at 32°. The respiratory capacity, however, of the lungs is increased so that they contain more air but less blood and therefore weigh less in hot than in cold climates.

The action of the Heart is diminished under the influence of a hot climate.—Digestive power is accommodated to the altered conditions of the system; it is less powerful and there is less appetite, because there is less demand for food.—The activity of the sudorific and sebaceous glands

* By Blagden and Fordyce.

of the Skin is much increased; the papillæ of the former becoming often obstructed and inflamed, giving rise to the condition of *lichen tropicus* or 'prickly heat.' A change sometimes takes place in the pigmentary layer, after protracted residence, producing the yellowish tinge supposed to be characteristic of 'Anglo-Indians.'—Owing to increased action of the skin the quantity of Urine is diminished; and also that of excreted sodium chloride. Less food yields less urea.—Some European residents complain of want of energy and other results of a depressed condition of the Nervous System; but there is strong reason to believe, and abundant illustration by example, that as much and as good work, bodily or mental, can be done in this country as in Europe; and that the want of definite employment and the habits of indolence and self-indulgence which that want engenders are more to blame than climate for lack of energy and wasted lives.

Effects of the Direct Heat of the Sun.—The study of this subject is of importance on account of the relationship between it and insolation or sunstroke, so-called.* In moderation, sunshine is of the greatest use and "though its intimate chemical and physiological effects on the human economy may be as yet unknown to us, we recognise its healthful influence in promoting all changes, in quickening capillary circulation, in stimulating gland secretion, and fostering growth and development."† In excess, however, the heating action of the sun's rays has a powerful deteriorating influence on the human body, giving rise, ultimately, to a pale, anæmic appearance with corresponding languor and debility.‡

From what has been said at the commencement of this

* Formerly erroneously designated heat-apoplexy.

† S. and M. *op. cit.*, p. 189. Advantage is taken of this vivifying and heating power, by the use of so-called 'air' or 'sun' baths in certain parts of Europe, where the patients under treatment expose the naked body for a certain period daily to the direct rays of the sun, the head being duly protected.

‡ How far this is due to heat pure and simple, as distinguished from heat *plus* rarified and moist air, is not yet definitely settled.

chapter as to the great heating power of the direct rays of the sun upon solid bodies, it can easily be imagined how careful it behoves those exposed to such influence to be. The extent to which the body temperature in general and that of the head, neck, spine and skin in particular are raised has not been satisfactorily determined, though it is well known that great risk is run by those whose skin does not act freely or who do not protect the head and spine sufficiently. Again, it has been found impossible as yet to separate the part played by the sun's heat in the production of heat-stroke, from the usual concomitants of rarefied or impure air, excessive humidity, etc. It is certain that young, active and healthy persons do not easily get attacked whilst on the other hand three things strongly predispose, *viz.*, debility, fatigue and dissipation. Amongst British soldiers drunkenness was formerly the chief predisposing cause.

It is well worthy of note that cases of heat-stroke in mid-ocean or at great elevation are extremely rare, notwithstanding the great power of the sun's rays, and this fact certainly strengthens the view that humid or impure (but not rarefied) air or some other atmospheric condition, plays an important part in bringing about an attack of heat-stroke. One notable difference there is, common to mid-ocean and great altitudes, as compared with other places, and that is the entire absence, or presence only in very small amount, of ground surface from which heat is continually being radiated back rapidly.* Lastly, the glare and intense

* I believe how, in opposition to first impressions, that the risk of heat stroke to a healthy person living above an altitude of 5,000 feet is extremely small, and that it is only when much fatigued or when from any other cause there is a temporary accumulation of effete products in the system, that there is danger. Of course, a sensible European will always wear a *solah topee* or at least a *terai hat* when obliged to be much in the sun, for though the risk may be small the results of heat stroke are most serious. Yet one sees people, ladies especially, driving about day after day in the sun with no real protection, save perhaps their abundant hair and, it may be, a parasol held over them by their syce, without any harm accruing; a thing they would not dare to attempt in the plains. This does not prove that sun hats are unnecessary; only that the risk is much less than at lower altitudes.

light reflected from all surrounding objects, and especially from the ground bathed in Indian sunshine, are perhaps not less trying to the unacclimatised visitor to India, than the heat which they accompany.*

A great deal has been written on this subject, but as usual in India, careful experiments are urgently wanted and would do more to settle the matter than volumes of writing.†

Thermometers.—As temperature, for meteorological purposes, is always observed by means of these instruments, it is necessary to understand the principle of their construc-

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* Blandford, *op. cit.*, p. 4.

† For further information the works of Parkes—Moore—Chevers—Fayrer, etc., may be consulted. Chevers gives reference to many important memoirs.

Fayrer (*v.* article 'Sunstroke,' Quain's Dict. Med., p. 1558) recognises three chief forms of Heat-stroke, *viz.*, (1) the *Syncopal* form or heat-exhaustion following on great fatigue, over-exertion or depression from any cause, during exposure to a high temperature: complete recovery common. This form is frequently seen amongst soldiers during a long fatiguing march in the tropics. (2) The *Asphyxial* form, sunstroke proper or the real *coup-de-soleil*, following exposure, particularly of the head and spine, to the direct rays of the sun. The symptoms are those of sudden and violent injury to the nerve-centres; death resulting from rapid failure of the respiration and circulation. Recovery is complete—tedious—or imperfect, ending in serious impairment of health or intellect—or the result may be fatal. (3) *Hyperpyrexial* form or thermic fever, an intense state of fever,—the result of the influence of heat on the nerve-centres, and through them on the vaso-motor nerves, and of the heating of the body generally, by the direct action of either artificial or solar heat,—may occur, quite independently of the immediate operation of the sun's rays. It comes on as frequently at night or in the shade, as in the day or in the sunshine, especially in persons who are exhausted by fatigue, over-crowding, depression from any cause, such as dissipation, want of rest, present or recent illness, and notably when the atmosphere is impure from overcrowding. The temperature of the body rises to 110° F., or higher. Recovery is often incomplete; or is followed by permanent impairment of health, and generally by intolerance of heat and exposure to the sun.—Chevers (*op. cit.*) gives a quaint list of the predisposing causes to heat-stroke, saying in conclusion, 'Numerous as the constitutional causes of heat stroke are, all Indian experience combines to show that Drunkenness is the chief.' Again, 'Long residence in the tropics does not strengthen our brains against heat-stroke, but no one is more secure against its attacks than an experienced, prudent Englishman, still young and with a well-preserved brain.' * * * 'Can one harden oneself against tropical heat? The impression which my experience has left is distinctly in the negative.'—The dark-skinned races are certainly less liable to sunstroke than the fair-skinned, especially negroes, but it is quite a mistake to suppose that Hindus and Mohammedans are not subject to this complaint. 'To a temperature of the air rising above a certain standard, all succumb; and the natives of India suffer like others, and die in numbers every year from *loo-marna* or hot-wind-stroke.' (Fayrer).

To face p. 295.

PLATE XVI.

METEOROLOGICAL INSTRUMENTS.

Figure 1. Shade Maximum Thermometer (Phillips'). *v.* also pl. xviii.

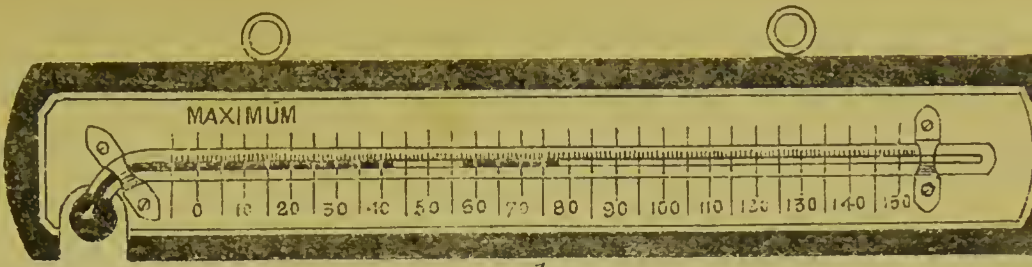
Figure 2. Shade Minimum Thermometer (Rutherford's). *v.* also pl. xviii.

Figure 3. (*a*) Standard Barometer (Fortin's Principle), showing the various parts of the same. (*b*) and (*c*) Part of the Scale—magnified. AB. The fixed scale of the barometer; CD. The moveable Vernier scale. (*v.* pp. 348-51).

Figure 4. Section of Cistern of a Barometer constructed on Fortin's Principle, showing the column of mercury in direct continuity with the mercury in the cistern, the bottom of the latter being made of Leather and its capacity regulated by means of the Moveable Screw below. The Ivory Stud is seen in the upper part of the cistern. (*v.* pp. 348-49).

Figure 5. (*a*) Rain-Gauge, showing Outer Cylinder, Funnel and Receiver. (*b*) Graduated Measuring Jar.

Figure 6. Lower portion of Wet-Bulb Thermometer, showing the Bulb covered with Muslin, from which depends the Cotton Wick dipping into a Vessel containing Water (not shown—*v.* plate xviii.).


MAXIMUM
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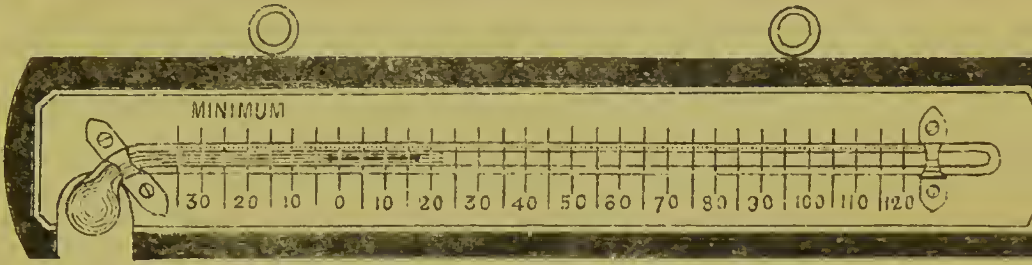
150

1.


MINIMUM
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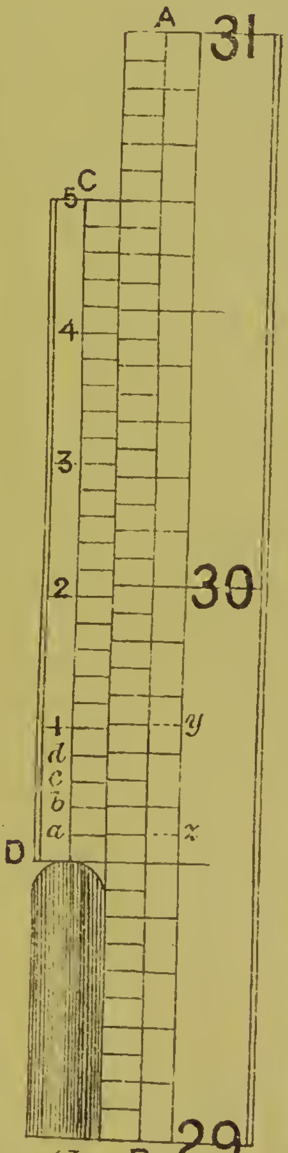
120

2

(a)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d
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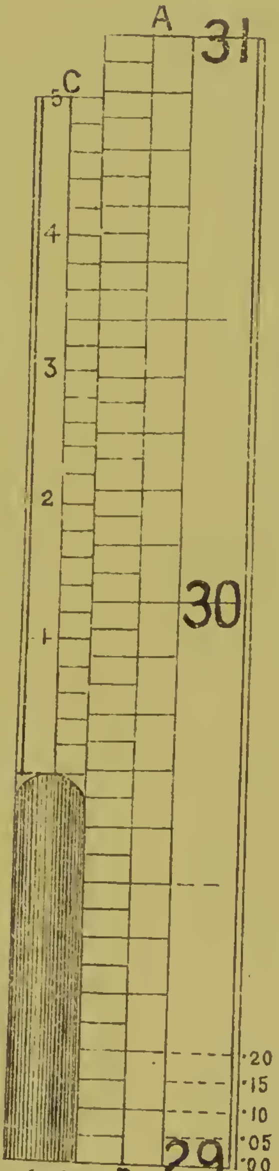
29

(b)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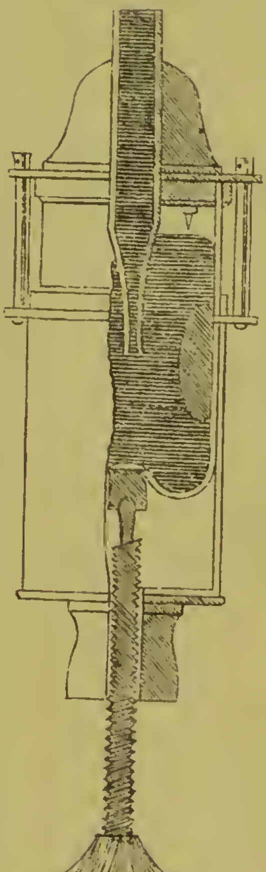
(c)

3.



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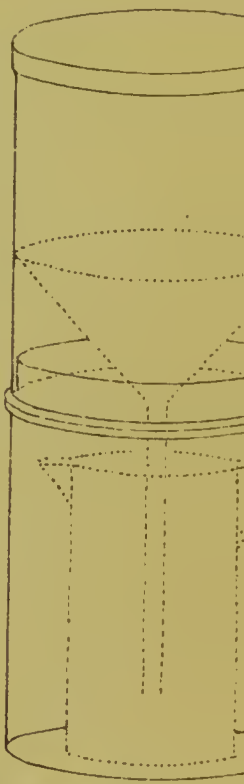
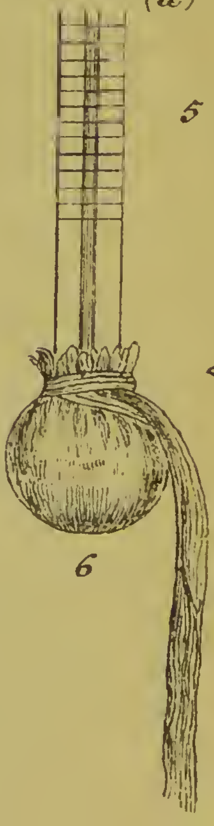


(a)

5



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tion and the different varieties in use. Most of them are used for ascertaining aërial or solar temperatures under varying conditions, but there are others for use below the surface of the ground, or in water, etc.

A thermometer consists essentially of a closed glass tube partially filled with mercury, alcohol or other fluid; the measurement of temperature depending on the difference of expansion between the glass tube and the contained liquid.* Mercury is most commonly used because of its low specific heat, great conducting power, ready expansion when heated, low melting-point and high boiling-point. In a mercurial thermometer the tube has a very fine bore and is expanded at the lower end into a cylindrical or globular bulb. Whilst filled with boiling mercury it is sealed, so that afterwards, by the contraction of the mercury, there is a vacuum in the hollow upper part of the stem.

It is graduated by immersing it in melting ice and marking on the stem the upper level of the contracted mercury, and thereafter suspending it in the vapour of water boiling at the ordinary atmospheric pressure† and marking on the stem the upper limit of expansion. The space between these two marks can then be graduated as desired.‡

Only two methods of graduation are now in common use, *viz.*, the Centigrade and Fahrenheit.§ The former is the more scientific and will ultimately become the only recognised scale.|| By this system, the lowest mark—freezing-

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* Air thermometers are theoretically the most perfect, but are not adapted for meteorological work.

† *i.e.*, 29·905 inches or 760 millimetres. A difference of 1 inch in the atmospheric pressure either way, as indicated by the barometer, means about 1·7° F. difference in the temperature at which water boils; below or above 212° F. according as the pressure is lessened or increased.

‡ For further details *v.* any text book on Physics, or article 'Thermometer,' Encycl. Britt., 9th ed.

§ The Reamur scale is also used in Germany and Russia: *v.* Special Works.

|| The Fahrenheit scale is still likely to be used for many years amongst English speaking nations, for ordinary meteorological purposes.

point—is 0° and the highest—boiling-point—is 100°, the intermediate space being divided into 100 equal spaces each of which is called 1 degree. In the Fahrenheit scale, the freezing point is marked 32° and the boiling-point 212°, the intervening space being divided into 180 degrees.

Varieties of Thermometer.—Five thermometers are in ordinary use in meteorological stations for determining the temperature, *viz.*—the ordinary thermometer, two maximum and two minimum thermometers. The temperatures observed by these are (1) the *shade temperature*, or temperature of the air at any given time; (2) the *maximum* and (3) the *minimum temperature of the air* during each twenty-four hours; (4) the *maximum temperature of solar radiation*; (5) the *minimum temperature of terrestrial radiation.* From the readings of (1), (2) and (3) is obtained the *mean temperature of the air* during each day of twenty-four hours.

The Temperature in the Shade, as stated above, is observed by means of three thermometers. The *dry-bulb thermometer* of the dry and wet-bulb hygrometer is used for ordinary purposes and consists of a simple mercurial thermometer graduated from − 20° F. to 130° F. By consulting it, with certain precautions, described below, the temperature of the air at any particular time can be ascertained. In this country it is usually read thrice a day at meteorological stations, *viz.*, at 8 A.M., 10 A.M. and 4 P.M.

To register the Maximum Temperature of the Air attained during twenty-four hours a *maximum thermometer* is used, either Phillips' or Negretti and Zambra's. In the former, the index is formed by a small portion of the mercurial column separated from the remainder of the mercury by a minute air bubble. So long as the temperature rises and the mercury expands, the index is pushed along the tube, but when it falls, the index does not fall back but remains at its furthest point and thus, by its distal extremity, indicates the highest temperature reached. In Negretti and Zambra's maximum thermometer the tube

is bent near the bulb and a minute obstruction* introduced. When the temperature rises, the mercury forces its way past this obstruction, but when it falls, the molecular attraction of the mercury does not suffice to allow the column to pass the obstruction and therefore the full length of the column remains in the tube, its distal extremity, as in the former case, indicating the highest temperature reached. Both patterns are reset by taking the thermometer off its hooks and lowering the bulb gently: sometimes, a gentle shake or swing is necessary. Both are hung a little off the horizontal, the bulb end being the lower.

For registering the Minimum Temperature of the Air the thermometer known as *Rutherford's Minimum* is almost universally used. It is an alcoholic thermometer, the spirit being coloured pink for convenience, and contains a glass index in the hollow of the stem. When the temperature rises the expanding alcohol flows past the index, but when it falls, the contracting alcohol, by capillary attraction, carries back the index with it. The upper end of the index being always flush with the extremity of the receding column, ultimately marks the lowest temperature reached by the column, and even if the alcohol again expands from a rise in the temperature, remains in its position.

Great care is necessary, in order to get results of any value, to see that the Exposure of the thermometers is the best that can be obtained. For this purpose it is essential that, whilst the direct rays of the sun do not fall upon the instruments nor upon the ground immediately beneath, there should be no obstruction to the free play of the air around them. Such conditions are not usually obtainable in a house or its verandahs, which have thick walls and other disadvantages; accordingly, a thatched shed of the pattern indicated in the plate has been generally adopted throughout India and thereby more uniform and trustworthy readings obtained.

To determine the heating power of the sun's rays, *i.e.*, the

* A thread of glass fixed by heating or simply a constriction in the tube.

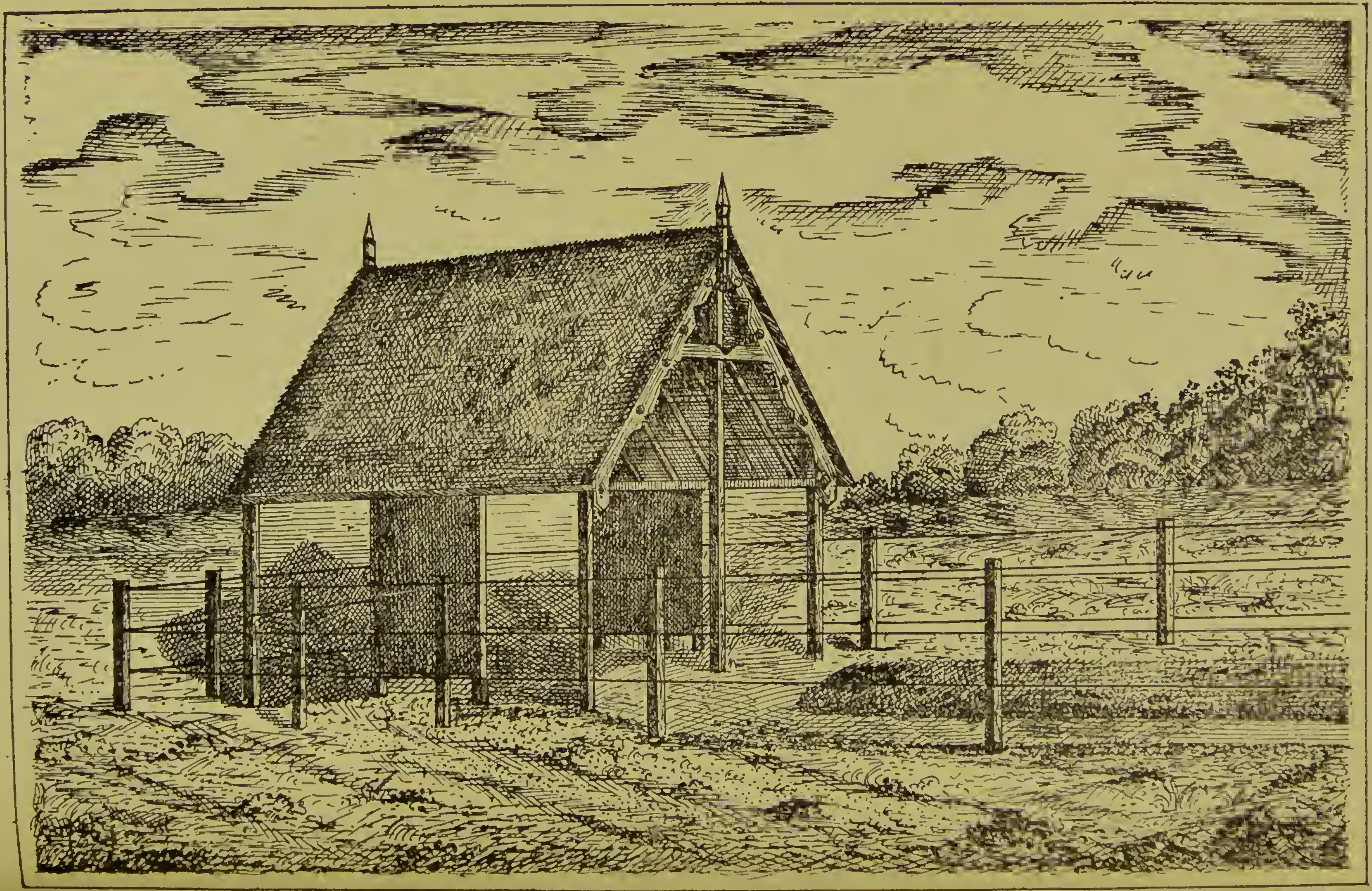
amount of Solar Radiation, appears at first sight a very simple matter but in reality it is not so, owing to several causes. An ordinary bright mercurial bulb acts as a spherical mirror and reflects instead of absorbing the heat rays. In addition, the bulb is cooled by wind, rain, etc. The *solar radiation thermometer* most generally used is therefore made by coating the bulb and part of the stem of an ordinary maximum mercurial thermometer with lamp black and enclosing it in a glass vacuum jacket as shown in the illustration. Even then the wind, etc., cools the outer jacket and this in turn interchanges heat by radiation with the inner bulb, so that the arrangement is not perfect. The highest reading is usually recorded as the 'maximum solar heat *in vacuo*,' whilst the excess of this temperature over that recorded by the maximum shade thermometer is considered to represent, approximately, the greatest amount of solar radiation which has occurred during the day. This thermometer is placed, of course, in direct sunshine and on a wooden stand at different heights according to different opinions, four feet being the regulation height in India.

To estimate Terrestrial Radiation a *minimum thermometer* of the same pattern as that previously described, or Cassella's modification of the same, is employed. It is placed on wooden trestles just clear of the ground, since the effect of terrestrial radiation is most marked where the disturbing influence of wind is least felt. When snow is lying on the ground it should be placed on it directly. Scott recommends laying a large, black board on the ground and placing the thermometer in a small groove cut in its surface to prevent rolling. In India, where the presence of grass cannot be insured, a pad is placed under the bulb. The difference in reading between this minimum thermometer and the minimum air thermometer is considered to express the amount of terrestrial radiation. It is not a perfect method by any means, but none better has been devised.

It is also becoming customary now to keep a record of

VIEW OF THERMOMETER SHED.

PLATE X.VII.



LITH: BY ROSS, BROS.

To face p. 298.

PLATE XVII.

THERMOMETER SHED AND ENCLOSURE FOR USE IN INDIA.

The frame work is generally made of teakwood, and the roof consists of a foundation of bamboo matting with a substantial thatching of straw, not less than six inches thick. The side screens, which are intended to shield the thermometers from morning and evening oblique sunshine, reflected sunshine and rain, should be similar to the roof, but not so thickly thatched. Of course, unless the sheds are properly set up, and the roofs well covered with straw, the thermometrical observations will be affected by solar influences. A clear space of about nine inches should be left below each side screen to admit air. A nice open position, at least fifty feet from any wall or obstruction, should be selected for the erection of the shed, and it should be carefully set up, the ends pointing north and south. The shed is painted green and enclosed by posts and fencing; the latter being telegraph wire, iron bars, or barb fencing. The cost of a complete thermometer shed made of teakwood according to the Madras pattern is about Rs. 120, and it lasts for upwards of twenty years, only requiring re-thatching about once a year. The ground surface of the shed is generally of red gravel, or in some places white sand. There is a path round the southern grass plot on which the radiation thermometers and rain gauge are exposed, as shewn in plate xviii. (*v.* Administration Report of the Meteorological Reporter to the Government of Madras, 1885-86).

To face p. 299.

PLATE XVIII.

GROUND PLAN AND SIDE VIEW OF THERMOMETER SHED AND ENCLOSURE.

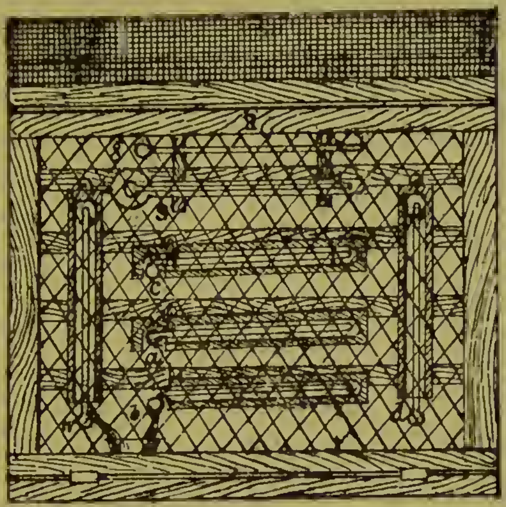
THERMOMETER CAGE.

The cage is carefully fixed to the centre pole of the thermometer shed, at a height of about three feet eight inches, so that the bulbs of the dry and wet thermometers are four feet from the ground. The substitution of these cages in place of the open boards has proved advantageous in securing the safety of the instruments. Each cage is made secure by a lock and key.

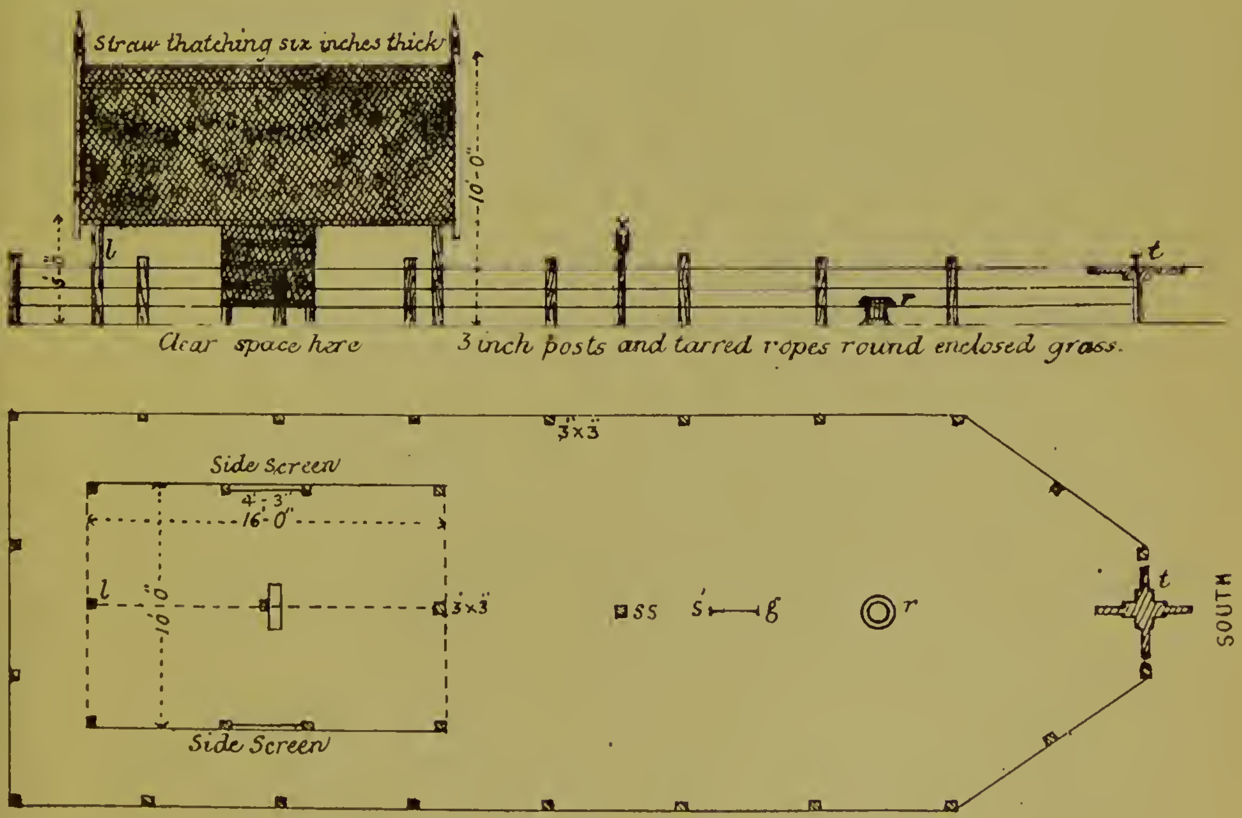
PLATE XVIII.

THERMOMETER CAGE.

SHOWING ARRANGEMENT OF INSTRUMENTS



The instruments to face due North and to be in a line with the centre of the two side screens.



PLAN & SIDE VIEW OF THERMOMETER SHED

LITH: BY ROSS, BROS.

the number of hours of Bright Sunshine *per diem,* and for this purpose an instrument known as a *sunshine recorder* is used. Of these instruments there are two classes, on the principle of the burning glass and photographic camera respectively The former type is specially suited to this country. It consists simply of a spherical glass lens beneath which a card ruled into divisions marking hours is placed in a curved holder. When the sun shines brightly, the rays are focussed on the paper, in which an interrupted series of linear marks is thus produced by burning, their total length indicating the duration of sunshine. It is worthy of note that the *intensity* of the burning is found to vary, being often greatest during the short periods of brilliant sunshine on cloudy days.

Having, then, at our command, these five thermometers, *viz.,* the ordinary dry-bulb thermometer, the shade maximum and minimum thermometers, the maximum solar radiation and minimum terrestrial radiation thermometers, with, in addition, a sunshine recorder, and supposing that each and all have their suitable exposure, as before described, we are in a position to investigate the temperature, etc., at any time and at any place fixed upon.

As a result of such observations it has been found that certain changes in temperature are *periodic* and others are *non-periodic.* The periodic or regular changes are sometimes termed *fluctuations* and the non-periodic or irregular changes *undulations.*

Fluctuations depend upon the earth's diurnal and annual motions, that is, on the alternations of day and night and of the seasons. The Diurnal fluctuation is greater on land than on water, inland than on the coast, in elevated places than at sea-level. On land, therefore, it is least on the shores of inter-tropical islands, as Ceylon and Singapore. The hottest time of the 24 hours is generally about 2 P.M., the coldest just before sunrise, the rise or fall of temperature between these extremes being nearly uniform. This applies to land stations; the maximum and minimum taking place

about an hour later at sea. The maximum does not coincide with but follows the culmination of the sun, on account of the gradual absorption of the sun's heat by the earth, upon which the temperature of the air depends. The Annual fluctuations depend primarily on the position of the earth in her orbit, according to which days are longer or shorter and more or less solar heat is absorbed in a given number of days They are greater on land than at sea, are greatest in the interior of extra-tropical continents and least at sea-level between the tropics; as, for example, at Singapore, where the annual fluctuation does not exceed 3° or 4°. They are greater as we advance towards the poles because of the greater obliquity with which the sun's rays strike the earth and because the differences of length between day and night increase; in the northern hemisphere, besides, there is a great preponderance of land, increasing absorption and radiation. As the diurnal, so the annual maxima and minima are not coincident with, but *consecutive* to, those relative positions of earth and sun which are most efficient in their production, and they occur, not in June and December, but in July and January.

Undulations of temperature are caused by winds, clouds, rain, or other non-periodic agents, cooling by evaporation or heating by radiation. These, like the fluctuations, are least in tropical countries near the sea. In different places their amplitude may exceed or be less than that of the fluctuations.

Temperature Observations in India.—The chief points to be ascertained in recording the temperature of any place are the *mean temperature*, the *range* and the *extremes*. These may be calculated for each day, month or year as desired, and this is actually done in practice.

The Daily Mean Temperature is most accurately obtained by taking the mean of hourly readings. This method can evidently be employed only at stations with a large staff of observers. For other places a close approximation to the true mean can be obtained from the readings at 10 A.M.

and 4 P.M. combined with the maximum and minimum readings. The formula used in India is

$$\text{Mean} = \frac{10 \text{ A.M.} + 4 \text{ P.M.} + \text{max.} + 2 \text{ min.}}{5} + \text{cor. for hours}$$

where the 'correction for hours' is obtained from a series of hourly readings taken at that station or at one similarly situated. The amount of the correction is usually small. By this plan there may be for any one day a small error, but for the whole month the mean temperature will be exact to a small fraction of a degree.

In India, during fine cloudless weather, the Diurnal Fluctuations of temperature are very regular. Just before sunrise the air is coolest, but as soon as the sun appears the temperature rises rapidly till between 8 and 9 A.M., and slowly till about 2-15 P.M.: then it sinks, slowly at first, afterwards more quickly till midnight, then slowly again till just before sunrise.

The Daily Range is greatest in clear weather and in the interior of the country,* least during rainy weather and near the sea.† In Sind, Beluchistan, etc., there is sometimes a difference of 35°—40° F. or more between the coolest and hottest hours, whilst in Bengal and the Carnatic it is much less and may be as low as 13° F. (Negapatam).

From the mean daily temperature is calculated the Monthly Mean Temperature by simple addition of the daily means and division by the number of days in the month, and in a similar way the Annual Mean Temperature is obtained from the sum of the monthly means. These means however are not nearly so important as the monthly and yearly ranges, for they do not give any idea of the extremes of temperature. Thus in one place the temperature may range annually from 80°—40° and in another from 65°—55°, but in both the mean will be about 60°, although they are by no means similar in reality.

The Annual Range is very important and varies very much in different parts of India, not only in magnitude but

* Especially N. W. India. † *v. ante*, p.

also in the duration and rapidity of the rise and fall. Its magnitude is greatest in the most northerly* and in the driest places, and least in the most southerly and wettest places. Thus at Leh a difference of 103° between the lowest and highest temperatures has been recorded in one year, whilst in Southern India the annual range is only about 30°—40°.†

In connection with this subject, however, it must be carefully noted that comparisons between the temperature ranges of different places have absolutely no value unless the instruments have all been carefully compared with standard ones and have the same exposure, as nearly as may be, in every case. On account of want of care in this respect much laborious work has been uselessly undertaken and necessarily discarded, and many wild and unfounded statements have been made.

As regards the Annual Periodic Variations in temperature, the "popular division of the year into a cold season, a hot season, and the 'rains,' holds good in the greater part of India, and fairly represents the more obvious phases of the climate."‡ The accompanying table brings out the above points for the chief stations of India and Lower Burmah.

Sudden and Irregular Changes of Temperature are not so marked in India as in other countries and when they do occur are temporary in nature and due to a sudden heavy fall of rain or, on the coast, to the setting in of a cool sea breeze in place of the hot land wind. They are generally a great relief and eagerly looked for. In Northern India, however, more frequent and irregular changes do occur suddenly, and as such changes have an important bearing

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* *i.e.*, places where there is the greatest difference between the longest and shortest day.

† Such is the uniformity of climate on the south-west coast of Ceylon, that the extreme range of temperature in the course of the year is only about as great as that experienced within 24 hours at Simla and little more than half that of a single day at Jacobabad.

‡ *v.* Blandford, *op. cit.*, p. 15.

on the production of chill, the subject is worthy of careful study.*

In this country the Intensity of the Sunshine is greater than in higher latitudes and the excess of temperature (solar radiation) registered by the maximum black bulb thermometer *in vacuo* as compared with the maximum shade thermometer is about 50°—70° F. as a rule. It is not however this excess *per se* which is so important hygienically, but the fact that the shade temperature is already high, *e.g.*, in Southern India the excess may be only about 58° F., but the shade temperature is much higher than in England and the risk of sunstroke correspondingly greater. At hill stations the excess is generally large, 70°—80° F., but the lowness of the shade temperature lessens the risk of insolation, provided the head and upper part of the spine are protected.† The actual number of hours of sunshine is also greater than in such a country as England, particularly in Northern India where the average appears to be about 9 hours *per diem*‡ as compared with about 4 hours in England.

MEAN AND EXTREME TEMPERATURES AND RANGES AT FIFTY-ONE STATIONS, CHIEFLY HILL STATIONS AND MILITARY CANTONMENTS.§ (Deg. Fahr.)

Stations.	Elevation in feet.	Mean Temperature of			Mean Highest Reading.	Mean Lowest Reading.	Annual Range.	Rise January to May.	Change May to July.
		Year.	Hottest Month.	Coolest Month.					
Kurrachee . .	49	77	87	65	107	45	62	20	− 1
Quetta . . .	5,501	58	77	40	99	15	84	26	+ 11
Jacobabad . .	186	78	96	57	118	32	86	34	+ 3
Mooltan . . .	420	76	94	54	114	34	80	35	+ 3
D. I. Khan . .	573	74	93	52	117	31	86	35	+ 4
Leh	11,503	40	62	18	90	−4	94	29	+ 15
Peshawar . .	1,110	70	89	50	115	29	86	30	+ 9

* *v. ibid.*, *op. cit.*, pp. 10—12. † *v. ante*, p.

‡ The actual average daily duration of bright sunshine in many parts of India is uncertain as yet, but is probably less than might be imagined in the absence of accurate observations.

§ After Blandford.

MEAN AND EXTREME TEMPERATURES AND RANGES AT FIFTY-ONE STATIONS, CHIEFLY HILL STATIONS AND MILITARY CANTONMENTS. (Deg. Fahr.)—*cont.*

Stations.	Elevation in feet.	Mean Temperature of Year.	Mean Temperature of Hottest Month.	Mean Temperature of Coolest Month.	Mean Highest Reading.	Mean Lowest Reading.	Annual Range.	Rise January to May.	Change May to July.
Rawalpindi .	1,652	69	89	49	114	29	85	32	+ 6
Murree . . .	6,344	56	71	39	93	24	69	26	+ 3
Sialkot . . .	829	73	91	52	117	34	83	33	+ 2
Lahore . . .	732	75	93	54	117	34	83	34	+ 1
Simla . . .	7,012	55	67	41	88	25	63	23	0
Delhi	718	77	93	59	116	40	76	30	− 2
Meerut . . .	737	76	92	57	112	37	75	32	− 3
Agra	555	79	95	60	116	40	76	34	− 7
Deesa. . . .	465	80	92	67	112	40	72	25	− 9
Abu	3,945	68	79	58	96	39	57	21	− 9
Neemuch . .	1,639	75	88	62	111	39	72	26	− 9
Ajmere . . .	1,611	74	89	58	112	34	78	31	− 7
Lucknow . .	369	78	92	61	114	38	76	31	− 6
Allahabad . .	307	78	92	61	116	40	76	31	− 7
Patna. . . .	183	78	89	61	110	42	68	28	− 4
Darjiling . .	7,421	51	61	40	72	25	47	14	+ 7
Hazaribagh. .	2,007	74	85	61	106	43	63	24	− 7
Berhampore .	66	78	85	65	109	46	63	20	− 2
Calcutta . . .	21	78	85	65	102	48	54	20	− 2
Dacca . . .	22	78	83	66	100	48	52	17	0
Chittagong . .	87	77	82	67	94	48	46	15	− 1
Sibsagar. . .	333	73	84	59	99	42	57	19	+ 6
Cuttack . . .	80	81	89	70	110	51	59	17	− 6
Saugor . . .	1,769	76	89	63	110	42	68	26	− 11
Jubbulpore . .	1,341	75	90	61	111	36	75	28	− 11
Pachmarhi . .	3,511	69	83	56	100	35	65	25	− 12
Nagpur . . .	1,025	79	93	67	115	46	69	24	− 14
Poona . . .	1,849	78	86	72	106	44	62	13	− 10
Bombay . . .	37	80	85	74	95	61	34	11	− 4
Belgaum . .	2,550	74	81	71	102	51	51	8	− 9
Sholapur . .	1,590	79	89	70	110	47	63	17	− 10
Secunderabad .	1,787	78	89	69	109	48	61	19	− 12
Bellary . . .	1,455	80	89	73	108	54	54	15	− 7
Bangalore . .	2,981	73	80	67	98	51	47	12	− 7
Wellington . .	6,200	61	66	55	80	37	43	11	− 3
Madras . . .	22	82	88	76	108	60	48	11	− 1
Trichinopoly .	275	82	88	76	106	60	46	12	− 3
Cochin . . .	11	80	84	79	95	67	28	3	− 5
Madura . . .	448	82	86	77	105	62	43	9	− 2
Galle	48	80	82	78	89	70	19	4	− 2
Rangoon. . .	41	79	84	75	104	58	46	8	− 5
Moulmein . .	94	78	83	75	99	58	41	7	− 5
Thyet Myo . .	134	79	87	68	108	45	63	17	− 5
Toungoo . .	181	78	85	70	104	51	53	13	− 5

HUMIDITY.

Under this heading there falls to be considered the Water Vapour present in the atmosphere, and thereafter the various manifestations of the same in the form of Dew and Hoar Frost, Fog, Mist and Cloud, Rain, Snow and Hail.

Water vapour is a most important constituent of the atmosphere owing specially to the fact that it is near the temperature at which it becomes liquid or solid and is nearly always in the presence of liquid water; so that temperature changes greatly affect the amount of vapour present.*

Wherever we have a surface of water or, what amounts to the same thing, a moist surface of any kind, evaporation is going on from it unless the air is saturated with vapour. The amount of vapour required to produce saturation depends simply on the temperature, a rise of temperature corresponding with an increase and a fall with a decrease of the amount required. Now, since the vapour in the atmosphere may be measured, just as the atmosphere as a whole is, by the *pressure* it exerts, so we may say that for any temperature there is a certain limiting vapour pressure which cannot be exceeded. If the pressure is below this then evaporation will be going on and will continue till this limiting pressure is reached. The vapour, when it reaches this limiting pressure, is said to be *saturated.* Suppose, then, we have a quantity of saturated vapour in presence of water at a given temperature: if the temperature rises, evaporation will recommence because the vapour, though saturated for the lower, is not saturated for the higher temperature. On the other hand, if the temperature falls, the amount of vapour is in excess of that required

* "Let us suppose for a moment that the atmosphere consisted of water vapour only and that the hydrosphere covered the earth uniformly with a liquid layer. The amount of this atmosphere, and consequently its pressure, would depend upon the temperature. Evaporation takes place from cold water, or even ice, but *at every temperature when the vapour exerts a certain definite pressure upon the liquid, evaporation is stopped, and the vapour is said to be saturated at that temperature.*" H. R. Mill, *op. cit.*

for saturation at this lower temperature, and some of it, accordingly, must be re-condensed into water.

As a matter of fact, the air temperature is continually changing and consequently the amount of water vapour is continually changing also. Sometimes, however, the air is completely saturated for a time, or exerts sufficient pressure to put a stop to the process of evaporation.

When water vapour at 32° F. exerts a pressure of 0·18 inches of mercury the air is saturated, but at 50° F. it must exert twice the pressure, 0·36 inches, and at 70° F. double the pressure at 50° F., 0·73 inches, which is another way of stating that air at a temperature say of 70° F. can hold twice the amount of water vapour held by saturated air at 50° F. but only half the amount held by saturated air at 90° F. It is thus evident, as may be seen also by consulting a table of the weight of vapour, that the amount of vapour which can be rendered insensible increases with the temperature, but not regularly; comparatively more is taken up at high temperatures. Thus at 67° F., 7·22 grains are supported in a cubic foot of air; at 72° F., 8·47 grains, or 1·25 grains more; at 77° F., 9·92 grains, or 1·45 grains more than at 72° F. Therefore, if two currents of air of unequal temperatures, but saturated with moisture, meet in equal volume, the temperature will be the mean of the two, nearly, but the amount of vapour which will be kept invisible is less than the mean and some vapour therefore necessarily falls as fog or rain. Thus one saturated current being at 67° F. and the other at 77° F. the resultant temperature will be 72° F. nearly, but the amount of invisible vapour will not be the mean, *viz.*, 8·57 grains per cubic foot, but 8·47 grains per cubic foot; an amount equal to 0·10 grains per cubic foot will therefore be deposited, and will become visible as cloud. Should this condensed vapour meet with air not saturated, it will be re-absorbed, partially or wholly according to the capacity of the latter.

The total amount of water vapour which is contained at any

time in a given volume of air and expressed in the pressure it exerts in inches of mercury or in grains of moisture per cubic foot of atmosphere, is termed the Absolute Humidity. For our purpose, however, this is not nearly so important as the estimation of the percentage of moisture present relative to the total possible amount which the air at any particular temperature might contain if saturated. In other words, it is the percentage of saturation which is so important. It is called the Relative Humidity and is expressed as so much *per cent.*, 100 being saturation.* When, therefore, the relative humidity is low the atmosphere feels dry and evaporation proceeds readily from moist surfaces such as the human skin; when, on the other hand, the relative humidity is high or approximates to saturation, evaporation proceeds very slowly and the air is said to be 'damp.' In such a case a very slight fall in temperature leads to saturation and consequent condensation of moisture. These properties of water vapour are of the highest importance and furnish an explanation, partial or complete, of many atmospheric phenomena such as evaporation, the formation of fog, cloud, rain, etc. Two points remain to be noticed. Firstly, that vapour in contact with its own liquid always tends to become saturated, but the saturation will not necessarily extend far from the surface of the liquid, if the vapour be mingled with air which retards its movement.† Hence at sea the humidity of the air is always high or near saturation. Secondly, on account of the low temperature at great elevations, water vapour, although its density is only half that of the air, is almost entirely confined to the lower regions of the atmosphere. Still, as a general rule, the air becomes *relatively* more humid as we ascend, for water vapour is always *tending* to ascend through the atmosphere,—tending towards a distribution which it can never attain,—as explained above, so that, as will afterwards be seen, at hill

* The relative humidity bears a distinct relation to the temperature at the time of observation; the absolute humidity refers only to the amount of water vapour present, independent of temperature.

† *v.* Blandford, Meteorologist's *Vade Mecum*, sec. 12, p. 108.

stations even during fine dry weather, the relative humidity is always much higher than on the plains below.

During evaporation or condensation important Thermal Changes take place. "The change of a pound of water into a pound of vapour requires the same expenditure of energy whether it takes place in a kettle boiling on a fire, or over the surface of a freezing pond."* Thus when the temperature of the air resting over the surface of a tank or moist ground is raised, evaporation commences, and heat being used up in the process, the air is cooled and continues to be cooled till the temperature of saturation is reached. In practice, owing to the fact that the partially saturated air is removed by wind, the process of evaporation generally continues at varying degrees of rapidity, throughout the day. Conversely, when air saturated with vapour is cooling by radiation, the vapour as it condenses gives out heat and so lessens the rate by lowering the temperature. In both cases the effect is to *retard the rate of the temperature changes*, and thus influence in a striking manner the local climate.

The Rate of Evaporation from a given surface varies with the temperature of the air, the state of the wind, the amount of moisture already present in the atmosphere, the nature of the surface itself and its exposure to solar action. The greater the heat the freer the evaporation, other things being equal; but the latter increases more rapidly than in proportion to the rise of temperature, because heat acts not only by promoting vaporization but also by augmenting the capacity of the air for humidity.† Wind favors evaporation by replacing air more or less nearly saturated by drier air, unless the current is itself moister than the air which it removes. The less the moisture already present above the evaporating surface the more rapid is evaporation: the process becoming gradually slower as saturation is approached. The shade afforded by trees, hills, buildings, etc., diminishes evaporation; and

* Mill, *op. cit.*, p. 108. † v. p. 306.

finally, a moist soil yields more vapour in a given time than an equal area of water.

Humidity in Relation to Health.—There is no doubt that the varying degrees of atmospheric humidity exercise upon the human body a very powerful influence; but such influence is so greatly modified by and so closely dependent upon other variable climatic factors such as temperature, pressure, winds, etc., that it is quite impossible to ascertain and define accurately the part played by humidity alone.

One very important point has before been alluded to and that is the fact that the moisture of the atmosphere acts as the *great regulator of the distribution of warmth* over the earth's surface, partly by retaining or obstructing the heat radiated back from the earth* and partly by the thermal changes consequent on the processes of evaporation and condensation. There is strong reason to believe that it is not so much the water vapour itself as the dust and moisture particles which absorb the heat radiated from the earth's surface, but in any case the effect produced is well-marked.

In places then where the air is more or less constantly damp the variations in temperature are generally gradual and the climate is said to be equable. As will be afterwards seen, this is characteristic of *island* climates, *i.e.*, climates of places situated on or near the sea, and while it suits the constitution of some people is apt to prove very trying and depressing to others. It is believed that when the air contains a large amount of moisture the excretion of carbonic acid from the lungs is increased, and *vice versâ*.

If the absolute humidity is low the respiratory functions are especially affected, and the amount of expectoration much diminished.

When the relative humidity is low and the temperature

* "The aqueous vapour [or condensed vapour and dust particles] takes up the [heat] motion, and becomes thereby heated, thus wrapping the earth like a warm garment, and protecting its surface from the deadly chill which it would otherwise sustain." Tyndall.

high, when, in other words, the air is warm and dry, as ordinarily understood, the process of evaporation from the skin is continually going on and the body temperature is maintained at safe limits. If the air is cold and dry the loss of moisture takes place principally from the lungs. Such air has frequently a most exhilarating effect and is especially valuable in the treatment of many pulmonary complaints and in the debility, when not extreme, following long residence in moist, tropical climates. Epidemics of small-pox and plague are generally checked by a very dry atmosphere.

In India the greatest danger to health is incurred when the temperature is high and there is at the same time a high relative humidity : and this for a two-fold reason. In the first place the process of evaporation from the skin is not active and when the air, as frequently happens, is very still, the surface of the skin and the clothes become saturated with moisture. In such a case the relief naturally afforded to the organism by the loss of heat consequent on evaporation is almost entirely wanting and the body temperature may rise to such a height as to endanger life.* In the second place a person whose body and clothing are bathed in perspiration may be suddenly exposed to a breeze, whereby rapid evaporation, followed by cooling of the body surface, causes sudden congestion of the internal organs and a serious 'chill' is received, resulting in pleurisy, rheumatism, hepatitis, dysentery, etc. The liability to suffer from chill varies much in different persons, as also the organ affected, but the abdominal viscera being most commonly congested, diarrhœa, dysentery, and hepatic abscess are very frequent affections in warm moist climates about the beginning and end of the 'rains.'

The general effect of long continued warmth and moisture of the air on European constitutions is the production of a feeling of languor which may amount to complete disinclination to mental or bodily exertion. The appetite is

* *v. ante*, p. 291.

lessened, but the tissue changes being markedly lessened also, the amount of subcutaneous fat is often increased. Certain diseases, such as malaria and cholera, find a particularly congenial home when to the ordinary conditions, such as excess of organic matter in the soil, etc., continued atmospheric warmth and moisture are added.

When the air is cold and moist there is a tendency to rheumatic and catarrhal affections, and great precautions are necessary in the direction of always wearing woollen clothing next the skin. Under such circumstances the kidneys become specially active whilst the loss of moisture through the skin is reduced to a very small amount.

It is not possible to lay down any definite rule regarding the degree of relative humidity most conducive to health, on account of its close relation to other climatic factors: it is generally stated to be between 70 and 80 *per cent.*, but the statement is of little value *per se.*

Estimation of Humidity.—The absolute or relative humidity can easily be calculated when the temperature and dew-point are known. The amount of aqueous vapour which air can retain without depositing it as dew or rain, varies, as we have seen, with temperature; and the Dew-Point at any time is *that temperature at which the quantity of vapour then present would be sufficient for saturation, so that any further depression would be attended with deposition of dew.* It is ascertained either *directly* by Regnault's or Daniell's Hygrometers,* or *indirectly* by the Wet and Dry Bulb Hygrometer, sometimes called the Pyschrometer of August.

Regnault's hygrometer consists of a glass tube, closed below by a cap of thin and highly polished silver, 1·8 inch in depth and 0·8 inch in diameter, a very sensitive thermometer passing through a cork in the upper orifice of the tube and descending nearly to the bottom of the cap.

* Other Hygrometers are Dines' (direct) and the Hair Hygrometer of Saussure (indirect). For their description *v.* any text-book of Meteorology, S. and M's Hygiene, etc.

From the same depth rises a thin glass tube, also passing through the cork: while an opening in the upper part of the instrument communicates with an aspirator. When an observation is to be taken, ether is poured into the tube until it is about half full and atmospheric air is drawn through the ether by means of the aspirator and the fine glass tube. As the air bubbles through the ether the temperature of the latter and of the silver cap in contact with it falls until the dew-point is reached, that is, until the air outside the cap is cooled to such a degree that it can no longer retain its moisture, which is deposited as a dew upon the silver. The immersed thermometer indicates the temperature at which this occurs, and it should be read at the instant of the clouding of the silver. Three or four observations are generally necessary to accurate determination, which may be thus made to 0°·1. The temperature of the air must be simultaneously noted.

Daniell's hygrometer is more portable and convenient than Regnault's, but the indicating thermometer is so small that determinations cannot be made nearer than to 0°·5. There is difficulty also in catching the precise instant at which the dew appears. The instrument consists of two spherical glass bulbs about $1\frac{1}{4}$ inch in diameter, communicating by a glass tube bent at right angles. One of these is black, the other transparent. A small mercurial thermometer with pyriform bulb is enclosed in that limb of the tube which communicates with the former, the bulb descending to the centre of the black sphere. Sufficient ether to fill this about three-fourths has been originally introduced, the air excluded as completely as possible by boiling, and the whole hermetically sealed. The other sphere is covered with muslin and the whole supported by a stand on which is fixed a second delicate thermometer indicating the air temperature. To take an observation the ether is first collected into the black sphere and the temperature of the air noted. Ether is then dropped upon the muslin. As it evaporates, the cold produced condenses the ether vapour

which fills the transparent sphere and the connecting tube, and so compels evaporation and consequent cooling in the black sphere. The mercury in the enclosed thermometer falls and, when it reaches the dew-point, a ring of condensed vapour appears on the black sphere at the level of the surface of the ether within. As the ether recovers its original temperature the ring gradually disappears. At the moment of its disappearance the indication of the enclosed thermometer gives another approximation to the dew-point, and the mean of the two observations is sufficiently near the truth for ordinary purposes.

These instruments, as above stated, give the dew-point directly, whilst the Wet and Dry Bulb Hygrometer, by a comparison of its indications, gives the same indirectly. This instrument consists of two similar thermometers, set at least one foot apart in a frame fixed four feet from the ground, with the precautions before described.* One gives the air-temperature in the ordinary way; the other the "temperature of evaporation." The bulb of the latter is covered with muslin which is kept constantly moist by means of cotton thread connecting it with a small reservoir of rain or distilled water fixed on the stand. The cotton should be perfectly free from grease which might interfere with its transmission of water to the bulb. As the moisture evaporates the bulb cools and the mercury falls;† and the less the humidity present in the air the more rapid is the evaporation and the greater the depression of the mercury. When the air is nearly saturated evaporation is very slow and the indication of the wet bulb thermometer is little lower than that of the dry bulb; at saturation they coincide

* *v.* p. 297.

† "In computing the dew-point from the depression of the wet bulb, it is assumed that the air around the bulb gives up heat sufficient to evaporate the additional quantity of water requisite to saturate it; and that, this atmosphere being constantly renewed, the wet bulb is kept at the temperature to which it is thus depressed". (Blandford). From which it follows that the air round the wet bulb must at all times circulate gently: the stagnant air of a room is therefore unsuitable, that of the thermometer shed (p. 297) generally fulfilling the requisite conditions best.

and their common indication is the dew-point. When the temperature is very low, as when it is freezing, evaporation still proceeds; but very slowly, because the capacity for moisture is low. The differences are then minute and observations require special care and precautions. Unless the air is saturated, the indication of the wet bulb thermometer will always be below that of the dry bulb and above the dew-point.

Having observed the difference between the indications of the two thermometers the dew-point may be calculated either by Apjohn's* or August's formula or by Glaisher's tables. Into the theory and practice of these methods for estimating humidity it is not necessary nor desirable to go here. In practice the humidity is, for all ordinary meteorological purposes, obtained from tables which shew the humidity corresponding to any given depression of the wet bulb, for all temperatures of the wet bulb. In India, Blandford's tables are most convenient.

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* This formula gives, not the dew-point itself, but the *Tension* of aqueous vapour of the dew-point in terms of the tension at the temperature of evaporation. The corresponding temperatures are obtained from a table, which expresses the tension or elastic force of vapour at various temperatures in inches or fractions of an inch of mercury. If a glass tube, closed at one end, whose inner surface has been moistened with water, be filled with mercury and inverted with its open end immersed in a vessel containing mercury, the level in the tube will be lower than in the ordinary barometer; because the upper part of the tube, instead of being a vacuum, is filled with aqueous vapour, whose tension or elastic force depresses the mercury and is measured by the amount of depression. So long as water is present above the mercury, to supply vapour, the tension is constant, however the space may be increased by raising the tube in the vessel, (provided the open end remain immersed); and if the tube be depressed, contracting the space above, some vapour will be re-converted to water and the tension will be the same, temperature and pressure being unchanged. The amount of depression of the mercurial column corresponding to every ordinary degree of temperature has been ascertained and tabulated. It must be added that if air were present, along with the aqueous vapour, the relation of tension to temperature would be unaltered: the only difference between the two cases being that *in vacuo* the space is saturated very rapidly with vapour, while more time is necessary if air be present.

Blandford prefers August's formula to Apjohn's, as being based on more accurate determinations of the elastic force of aqueous vapour and as simplifying calculation by adopting 29·7 as a mean barometrical pressure. The error involved in this assumption is unimportant except at hill-stations, where corrections must be applied. In comparing meteorogical observations it is necessary to ascertain and bear in mind the formula which has been used.

The Absolute humidity or total amount of aqueous vapour present in the air at any given time is expressed in grains per cubic foot and may be estimated (1) experimentally, by drawing a measured amount of the air through a drying tube and ascertaining the resulting increase in weight, (2) by determining the dew-point, directly or indirectly, and thereafter consulting a table giving the quantity of moisture which saturated air contains at different temperatures.

Atmospheric Humidity in India.—One of the chief peculiarities of Indian climates as a whole is their variability with respect to humidity, and not only so, but when the humidity is at its maximum at certain parts of the country, the air in other parts is at its driest. Examples of this will be given afterwards.

With respect to the Diurnal Variation in humidity, the latter* may almost be said to vary inversely as the temperature, so that the air is dampest in the early morning before sunrise, becomes drier as the temperature increases, the maxima of temperature and dryness corresponding, and finally becomes damper again towards evening as the temperature falls.

The Annual Variations in humidity are very curious and interesting and undoubtedly play a most important part in regard to outbreaks of disease, more especially malaria and dysentery. It must not be forgotten that when the relative humidity begins to rise rapidly, other conditions, such as marked alteration in the level of the ground water, are generally brought about, and accordingly it is extremely difficult to make out whether the increased humidity is a true disease-producing factor or merely a danger signal as it were.

The rainy season from June to September is also the dampest for nearly all parts of India, the percentage of humidity averaging about 75—85; at certain stations, like

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* It is *relative* humidity only which is here referred to.

Darjeeling and Mercara, it may be as high as 95—99 or even saturation for July and August. At a few stations in the north, the winter is the dampest season, July being the driest month, as mentioned below.

The driest time of the year varies very much in different parts of India, *e.g.*, on the coasts of Bengal and Orissa, November or December are the driest months, in the interior of Bengal and Assam it is April, May in the Punjab and Upper Sind, June at Quetta, Peshawar and Leh. When it is driest on the east coast of Ceylon and the Carnatic, the humidity on the west coast and in the north is at its maximum.

The Geographical Distribution of humidity in different parts of India is stated by Blandford to vary according as moist or dry winds are most prevalent. The part played by winds in thus influencing the degree of humidity is most important and will be afterwards referred to.

MEAN ANNUAL HUMIDITY OF THE SEVERAL PROVINCES OF INDIA.*

Provinces.	Rel. Hum.	Provinces.	Rel. Hum.
Ladak	49	Orissa	76
N. W. Himalaya (lower ranges)	62	Central Provinces (southern)	59
Nepal Valley . . .	72	Berar and Khandesh. .	53
Sikkim Himalaya . .	84	Konkan and Surat . .	72
Baluchistan . . .	50	Deccan	55
Sind† and Cutch . .	50	Hyderabad and Bellary .	54
Punjaub Plains . . .	55	Northern Circars and Godavery	71
Rajputana	48	Carnatic	67
Guzerat†	47	Mysore	66
Central India Plateau .	50	Malabar and Coorg . .	79
Nerbudda Valley . .	55	Ceylon	80
N. W. Provinces and Oudh	59	Arakan	80
Behar	65	Pegu	77
Bengal	80	Tenasserim . . .	80
Assam	80	Bay Islands . . .	81
Chutia Nagpur . . .	57		

With reference to the foregoing table it must be noted that different parts of one and the same province or even district may shew considerable differences owing to local peculiarities.

Thus, at the Alipore Observatory near Calcutta the average of February and March is 69, but in the *more closely-built* suburb of Chowringhee only 66; a difference of 5 *per cent.*

DEW.

When on a clear night heat is rapidly radiated from the earth's surface and the temperature falls below the satu-

* After Blandford. † Exclusive of the coast.

ration point of the water vapour present, moisture is condensed upon all exposed objects in the form of small drops or, in some cases, minute ice crystals. In the former case it is called Dew, in the latter case it is called Hoar Frost. It was formerly supposed that the moisture found in the morning on objects exposed to the night air was simply derived from the water vapour in the air. It is now known, however, that this is not the case, but that a large amount of the condensed moisture found is derived from water vapour which is exhaled from the earth, blades of grass, etc.*

Whatever favours the process of cooling by radiation favours also the abundant formation of dew, *e.g.*, absence of clouds or other form of condensed water vapour, absence of trees, buildings or any other obstructions. Movement of air is unfavourable because it removes partially cooled particles before they have been sufficiently chilled to deposit. Good conductors such as metallic bodies do not generally exhibit dew, because they receive continuous and rapid supplies of heat from the earth. Foliage and fibrous structures like clothing being good radiators and bad conductors receive the most copious deposit† ; to which a moist atmosphere and a still and cloudless night are most conducive. But, as stated above, the question is not simply one of the condensation of moisture from air cooled below its dew-point. The exact nature of the processes

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* It is impossible here to go into the complex question of dew-formation. The subject has lately received a large amount of attention from Mr. Aitken (whose papers will mostly be found in the Proc. and Trans. R. S. Ed.) the Hon. R. Russell and others. The latter has published an interesting pamphlet, *Observations on Dew and Frost*, Standford, and his conclusions are given in detail in Nature for 29th December, 1892. The latest observations appear to be those of Herr Wollny, *v.* Nature for 23rd February 1893, who concludes that 'Dew depends partly on evaporation from the ground, partly on transpiration. It is at present doubtful [?] whether precipitates from the air share in it or not. A cloudy sky weakens the cooling process without stopping it wholly. * * * The more moisture there is in the ground the more water is evaporated from the ground and the plants * * *'.

† According to Herr Wollny, however, the excess of moisture found on 'organic' bodies as distinguished from 'inorganic', is simply due to their greater power of hygroscopic absorption.

involved in the deposition of dew is not yet fully understood.*

Hoar frost is simply dew frozen after deposition. It is commonly well seen during the colder months of the year in certain parts of Upper India and in the more sheltered positions at hill stations situated at an altitude of about 7,000—8,000 feet or more.

HAZE.

In India, particularly in Northern India, the sky is rarely very clear, nor the blue colour very intense; such pallor of the sky being apparently due to a haze arising either from thin diffused cloud-matter at a high level or else to the dust which is daily carried up by the convection currents in the heated atmosphere. In other words, it is sometimes a pure dust haze, at others it is made up of moisture condensed on dust particles. This will be again referred to under atmospheric dust, and is only now alluded to, in order to point out its possible connection with reference to the formation of mist, cloud, rain, etc.

MIST AND FOG.

As a matter of fact fog, mist and cloud, rain, snow and hail, may all be looked upon as examples of the same phenomenon occurring under varying conditions, this phenomenon in itself being simply the condensation of water vapour in the atmosphere as a natural occurrence. The most important discovery in this connection of late years was that of Mr. Aitken,† who showed that water almost never condenses except on a solid particle. He proved this by showing that, if moist air be kept perfectly free from dust, the temperature can be lowered much below the dew-point without condensation occurring; but that as soon as dust is admitted to the air condensation at once takes place, each dust particle forming a nucleus upon which the moisture condenses. In all cases, therefore, of condensa-

* Carefully conducted experiments on this subject, in India, would well repay the trouble taken.

† v. Nature for 1881—85—88 and 90 and references given therein.

tion of atmospheric moisture, whether in the form of mist, fog, rain or cloud, etc., the presence of dust particles is essential to the commencement of the process.

Fog and Mist are to a large extent interchangeable terms and are often applied indiscriminately to the same phenomenon.* In both cases they are caused by a sudden cooling below the dew-point of masses of moisture-laden air. Where the dust particles are very numerous and the temperature suddenly lowered, each particle will only receive a relatively small coating of moisture. And it may happen that owing to the absence of wind, the minute globules thus formed remain suspended for a very long time in the air. Such fogs, of which the nuclei are minute particles of carbon derived from the smoke of coal fires, are unfortunately only too common in the great cities in England and elsewhere, more particularly London, and may last continuously for 8 or 9 days. In colour they vary from pale yellow up to dark brown,—'black fog' so called,—and may so obstruct the sunlight as to necessitate the continued use of artificial illuminants in the houses and streets for days together.

Mists are comparatively uncommon in the plains of India save along the course of large rivers or over marshy land during the cold weather. They are soon dispersed by the increase in temperature after sunrise.

CLOUD.

Clouds, which are simply mist at high altitudes, are continually forming, dissolving, and re-forming according to varying temperatures of different masses of air. The

* By Blandford, the meteorological sign (*m*) is reserved for the haziness of the sky above alluded to, whilst the term fog (*f*) is used for the visible masses of condensed vapour that are seen over damp places in the evening or early morning. "Fog differs from mist in not wetting solid objects with which it comes in contact." Mill, *op. cit.*, p. 114. 'A dry fog may thus result from cold causing condensation on a very large number of dust-particles which are radiating heat rather freely, and a damp mist from partial condensation from supersaturated air on a comparatively small number of dust-particles not radiating freely owing to a clouded sky. * * A dry fog is the work of cold radiating particles, a wet mist is the work of cold air mixing with warm.' Russell, *op. cit.*

various shapes and appearances of clouds have been the subject of observation from unknown ages, by those to whom weather changes are naturally of extreme importance. "To an experienced eye" says Blandford "the forms and movements of the clouds and the general aspect of the sky are eloquent of impending weather, but save seamen, and among intelligent and observant nations, farmers and herdsmen, there are but few who have learned their language and can rightly interpret it, while such knowledge as these possess is for the most part empirical and little capable of being harmonised with the facts and translated into the language of physical science. Among meteorological observers of the ordinary class, it is certainly rare; it cannot be learned from books and unlike the art of managing and reading a thermometer or barometer, cannot be imparted in a few easy lessons."

For a long time, the simple classification proposed by Howard has been in use. According to this classification clouds are divided into four principal forms. (1) *Cirrus.* (2) *Cumulus.* (3) *Stratus.* (4) *Nimbus.*

Cirrus cloud is that which is commonly seen floating far above other clouds, and which is made up of streaks or fibres of clouds parallel or divergent or forming a fleecy brush or network. Under various conditions these cirri have the appearance of horses' tails, of the teeth of a comb, fine wisps of cotton-wool, etc. They are the highest clouds because the lightest, and reflect the sun's rays after sunset long after lower strata of cloud are dark. They have been known to retain their form unchanged for two days while a strong breeze was blowing lower down, showing that they are raised out of the reach of ordinary atmospheric disturbances. They probably consist of frozen water.

The term Cumulus is applied to those large, billowy cloud masses which so commonly surround the horizon during fine weather, the base or under surface being more or less flattened, the upper surface rounded. After the sun has risen the atmospheric strata in contact with the

earth become heated; so that, their specific gravity being diminished and their capacity for vapour increased, they rise, carrying up with them in solution the vapour which they had absorbed during the night and early morning. Reaching colder regions of the air, the vapour of the ascending current is condensed to cloud which, descending slowly, meets the ascending current and condenses, partially or wholly, its moisture. Thus a mass of cloud continually increasing in size is formed. Were the supply of vapour for condensation equal from all sides the cumulus would be spherical in form; but, as the under surface is in contact with air not fully saturated and, therefore, not yielding condensed vapour, the shape is hemi-spherical or conical as has been described. The cumulus is formed only by day, then only the conditions necessary for its development being fulfilled. It disappears late at night; because at that time the upper atmospheric strata have increased in temperature and vapour-absorbing power, while the lower layers are cooler and cease to supply an ascending vapour-bearing current.

The Stratus is a widely-extended, continuous, horizontal sheet of cloud, often forming at sunset, when the air is calm; the atmospheric strata near the earth becoming cooled below the dew-point, and depositing dew on the surface and cloud above. It increases by growth at its upper surface as the higher layers cool. The mists or fog-banks which rise from valleys, lakes, etc., during night and early morning, and which are dispersed by the rising sun, belong to this class of cloud.

The Nimbus, or cumulo-cirro-stratus as it is sometimes called, is the typical 'storm-cloud' and consists of a dark grey or black sheet of stratus cloud, above which the cirrus* is spread, while it presents a mass of cumulus laterally. From its under surface rain is usually falling.

It is evident to any observer that these four forms are

* Called 'false' cirrus in contradistinction to the true cirrus of great altitude.

the chief types of cloud shapes and that there are several fairly common forms which are intermediate or a compound of two primary forms, *e.g.*, Roll-Cumulus, Cirro-Cumulus, Cumulo-Stratus, Cirro-Stratus. But it must be observed that such terms are by no means exact and bear no relation to the altitude of the particular cloud alluded to. It appears probable, moreover, that the forms assumed by cloud masses are largely dependent on temperature and also that certain forms are more or less characteristic respectively of dry or wet weather. As a result of many years observation and experience a scheme applicable to all parts of the world has been proposed by Messrs. Abercromby* and Hildebrandsson, which will "probably be the basis of the future classification of clouds, and which recognises the very important distinction between such as are characteristic of fine, and such as betoken or accompany rainy weather."

The following is the proposed classification :—

MESSRS. HILDEBRANDSSON AND ABERCROMBY'S PROPOSED SCHEME OF CLOUD CLASSIFICATION.

a. Discrete tending to rounded forms (principally in dry weather).	*β. Extended and sheet-like forms (rainy weather).*
A. Highest clouds, mean height 30,000 feet.	
1. Fibre cloud [*Cirrus* or mare's tails].	2. Thin cloud veil [*Cirro-stratus*].
B. Medium elevation 13,000 to 20,000 feet.	
3. Small globular cloudlets, shining white like silk, 20,000 feet [*Cirro-cumulus*, mackerel sky].	5. Thicker ash-coloured or bluish-gray sheet, 17,000 feet [*Strato-cirrus*].
4. Larger globular, like white wool, 13,000 feet [*Cumulo-cirrus*].	
C. Lower clouds, 5000 to 7000 feet.	
6. Great rounded masses or rolls of gray cloud [*Strato-cumulus*].	7. Ragged sheets of gray cloud from which rain commonly falls [*Nimbus*].

* For an interesting account of cloud forms and formation *v. Weather*, by the Hon. R. Abercromby, International Scientific Series, and other writings of the same author.

D. Clouds in ascending air currents.

8. Heap cloud [*Cumulus*]. Summits at 6000 feet; bases at 4500 feet.

9. Storm (thunder) clouds [*Cumulo-nimbus*]. Summits 10,000 to 16,000 feet; bases 4500 feet.

E. 10. Elevated fogs. Below 3500 feet [*Stratus*].

Estimation of Cloud.—A perfectly clear sky is regarded as 0, whilst one completely overcast is regarded as 10.* To estimate the degree of cloudiness, the observer looks midway between the zenith and horizon and turns slowly round, comparing the clear parts of the sky with the clouded. The usual times for observation are the same as for temperature and pressure. To observe both the shape and movements of clouds due allowance must be made for perspective. The velocity of movement of a cloud can sometimes be measured, under favourable circumstances, by noting the time taken by its shadow to traverse a space of country, of which the distance is accurately known.

In all these observations care and practice are necessary if useful results are to be obtained.

Cloud in India.—It appears extremely probable that the elevations given in the foregoing table, made from European observation and measurements, would have to be considerably raised in this country.† Careful observation, by the unaided eye, of the clouds as seen from the neighbourhood of Ootacamund,—where the view extends from the summit of the western *ghâts* (8,000 feet) to the Mysore plateau and the plains of the Coimbatore district,—have strengthened the writer's belief in the approximate accuracy of the foregoing classification, with the above reservation as to the relatively greater elevation in the tropics of the various cloud forms therein given.

As to the lessons to be learnt from clouds it is impossible to write much here. The higher clouds act as 'floats' indicating the direction of the air currents in the elevated region of the atmosphere. This speed may be very great, and according to one observer the average rate of movement

* This may, of course, be expressed as a percentage, 100 being a completely overcast sky.

† Blandford.

of cirrus cloud is 40 miles an hour* or about three times as fast as the surface winds. The study of cloud movements will ultimately, no doubt, prove both interesting and instructive, but at present nothing is known bearing specially on the subject of hygiene†.

In India during cloudy weather the days are relatively cool and the nights hot, the clouds acting as heat-curtains preventing access of solar heat during the day time and checking the loss of heat by radiation from the earth's surface at night. Cloudy days and clear nights are therefore the pleasantest in the tropics and the opposite conditions correspondingly unpleasant. When the air is very moist at night and the sky completely overcast, with absence of rain, the most trying weather conditions are experienced.

July is the cloudiest month throughout the greater portion of India, *i.e.*, at the height of the rainy season, and August is almost as cloudy. The exceptions are Upper Sind, the Punjâb, and Baluchistan where the cloudiest months are February and March.‡ The season of clearest skies or greatest serenity varies more than the foregoing according to locality, being as early as October in the Punjâb and as late as February at Bellary and Dharwar. Further south than that the monthly mean is never very low. The mean cloud proportion is below 5 throughout India save in Assam and Sikkim, the Carnatic, Ceylon, and the southern parts of Pegu and Tenasserim. In different months and at different places it may range from 0·5 to 9·5 or even 10 at stations like Mercara.

RAIN.

The exact conditions relating to the formation of rain are as yet imperfectly understood, but speaking generally, when a mass of vapour-laden air is cooled below its dew-

* Which is not astonishing when one considers "how small is the retarding friction at great heights in the atmosphere." Blandford.

† "When a cyclone is forming in the bay [of Bengal], cirrus cloud from the S. W. is often seen passing over Bengal before there is any other distinct indication of its existence." *ibid.*

‡ *cf.* humidity.

point, the air being at the same time comparatively free from dust particles, a large amount of vapour will be condensed and each dust nucleus will become the starting point of a rain drop. Rain may thus fall from a cloudless sky, but as a rule it comes from clouds. It is supposed that the upper part of a cloud is freer from dust than the lower part; hence relatively large drops are formed in the upper part which, as they fall, absorb the smaller ones beneath, till ultimately they become large rain drops that fall towards the earth's surface at a rate which increases with their increasing size.

Upon the altitude of the rain-forming cloud and upon the temperature and degree of saturation of the atmospheric strata near the earth's surface depends the question of the originally condensed moisture ultimately falling as rain upon the earth. If the cloud is floating very high and between it and the earth is a mass of warm and relatively dry air, the condensed moisture will tend to evaporate and may be carried upwards again to become once more condensed: if, on the other hand, the cloud has formed at a low level and there is comparatively cool and moist air between it and the earth, instead of disappearing into vapour, the drops will become larger and will ultimately reach the earth as a heavy shower of rain.

The conditions for an abundant fall of rain are most perfectly fulfilled when a warm, vapour-laden sea breeze blows against a lofty range of hills and is forced to rise. Owing to the dynamical cooling of the air which thus results* a great and rapid condensation of vapour takes place and sheets of cloud are formed from which an enormous quantity of rain falls. The steeper the slope the greater the precipitation. As the wind continues its journey over the mountain tops and descends on the other side the air begins to grow warmer† and any moisture it

* *v. ante*, p. 287. The cooling is not to any large extent due to the 'chilling effect' of the mountain mass as is so often asserted.
† *v. ibid.*

contains is evaporated, so that the clouds disappear and the wind sweeps over the low country with a relatively low humidity and becomes a drying wind, causing increased evaporation of moisture from water and land surfaces and from objects in general such as clothing, vegetation, buildings, etc.

Cherra Punji in the Khasi hills, long renowned as having the highest recorded rainfall in the world, is a remarkable illustration of the combination of these favouring conditions. "The Khasi hills rise abruptly from the *Jhils* of Sylhet, which being but a few feet above sea level, and receiving the copious drainage of the hills that surround Cachar and Sylhet, present, during the rainy season, a broad sheet of water, from which emerge a few villages built on mounds and the low ridges locally termed *tilas*. Over this low inundated tract sweeps the south-west monsoon from the Bay of Bengal; and, meeting the Khas hills, is abruptly driven up to a height of 4,000 feet, before it resumes its course towards Upper Assam and the Eastern Himálaya. * * * Cherra Punji is surrounded, or nearly so, by vertically ascending currents of saturated air; the dynamic cooling of which is the cause of the enormous precipitation which has made this place famous."*

Effect of Rainfall upon Health.—The amount of the rainfall at any place, which itself depends chiefly on the local physical conditions and upon temperature and winds, has a very important influence upon health, this influence being (1) general and (2) individual.

In a country like India the influence of rainfall upon the General Health and well being of the community is very marked and of extreme importance. The failure of the crops and consequent famine resulting from a deficient rainfall is too well known to need any further explanation. On the other hand, an excessive fall of rain occur-

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* Blandford.

ring suddenly, may cause great damage and widespread distress; or again, a large annual fall, coupled with peculiar local conditions, may bring about a water-logged condition of the ground, from which may result a large and serious increase in malarial and other diseases. Yet again, except in the largest towns, a deficient rainfall for one or two seasons not only leads to famine from a scarcity of food grains, but also increases the prevalence of special diseases from the drinking of filthy and polluted water, and many other less noticeable evils.

The influence of rain upon the Health of Individuals is more temporary and consists chiefly in the danger of chill to those who are exposed to a wetting when clad in miserable cotton cloths and who have neither knowledge nor means to avert the effects of such chilling. At any large hospital such influence is easily recognisable, and as surely as heavy rain has fallen, with its usual accompaniment of a cold wind, so surely does the number of cases of pleurisy, pneumonia, rheumatism, dysentery, bronchitis, etc., suddenly undergo a distinct increase. The relationship between rainfall and cholera is often very marked. If cholera is prevalent, slight showers of rain generally increase the amount of the disease, whilst heavy rain will almost certainly put an end to the outbreak, probably owing to the thorough cleansing of the ground surface and subsoil. The seasonal prevalence of certain diseases in India and their correlation with other factors, such as insufficient or unsuitable clothing, food, habitation, etc., is a subject well worthy of far more systematic study than has yet been given to it.

Estimation of Rainfall.—The total amount of rain falling at any one time in a place is estimated by means of a Rain Gauge. Of these instruments there are various forms, the simplest being that of a bottle into which is inserted a metal funnel. For meteorological purposes, however, greater accuracy is required and an instrument constructed as follows is used. (*v.* illustration). It consists of an outer

cylinder of such a height that its mouth is exactly one foot above ground level whilst the base is slightly buried in the ground to fix it and prevent its being blown over or upset. Inside this cylinder is a metal funnel which fits accurately, and underneath the funnel is placed a receiver, generally a glass vessel* with a lip to facilitate pouring, and into which the tube of the funnel passes. In addition, there is a graduated glass vessel into which the water is carefully poured from the receiver when a measurement is to be made. "The measuring jar is divided proportionately to the area of the gauge, the diameter of which should always be an exact dimension, 5·00 inches or 8·00 inches, as it is then easy, if the original measuring jar is broken, to obtain a new one precisely adapted to the funnel. It is thus graduated. Take a 5-inch guage; if the diameter be 5 inches the area is 19·64 inches, therefore a rainfall of an inch, *i.e.*, 1 inch deep over the whole of a certain place or district, would in this rain gauge deposit 19·64 cubic inches, or 4958 grains of water. It is found in practice most convenient to make the jar hold ½ an inch. Therefore 2479 grains are poured in and the jar is marked with a line representing 0·50 or ½ inch; sub-divisions are similarly marked and so finally the jar has fifty divisions, one for each 0·01 inch and is figured at ·10, ·20, ·30, ·40, and ·50."†

Float gauges were formerly in common use but are now almost entirely abandoned on account of their radical defects in working. A good many gauges of the old Madras pattern are still in use. In these the diameter is about 4·7 inches so that 1 inch of rain is equal to 10 ounces of water and can be measured with an ordinary ounce glass. The gauge in ordinary use throughout India at the present time has a diameter of 5 inches. It should be placed on level ground, at least as many feet from trees, buildings, etc.,

* Or metal can with a lip. The graduated measuring jar must *never* be used in place of the receiver.

† G. J. Symons, F. R. S. Each one-hundredth of an inch is generally called a *cent.*, so that a fall of 0·5 inches would be 50 cents.

as these are high. Old gauges should not be abandoned until at least two years after the new ones intended to replace them have been established; in order that the two sets of results may be satisfactorily compared. When very heavy rain falls it should be measured as soon as the fall has ceased. In the case of snow $\frac{1}{12}$th of the average depth is counted as rain.* Hail is allowed to melt in the cylinder and the resulting water measured as rain. The water condensing from dew and fog is measured, when measurable, as rain,† though its immediate source is really very different according to recent researches.‡

Rainfall in India.—By means of the rain-gauge the Rainfall of any place can be accurately measured. From the returns thus made available, a knowledge of the rainfall throughout the Indian Empire has been obtained.

The total amount of rain that annually falls in India is very unevenly distributed, particularly in Northern India,§ where it ranges from Cherra Punji in the Khasi hills on the east with an average annual fall of 500—600 inches to Jacobabad in the west with an annual average of 4·50 inches. In Southern India the relative positions are, roughly speaking, reversed so that the west coast receives a far larger quantity of rain than the east coast. A glance at the accompanying plate will show this point clearly. Another fact of immense economic importance is that it is just at those places in which the rainfall is relatively scanty that it is also precarious, whilst in the rainiest parts the fall is most regular. To this rule, however, there are

* This is a rough method and not to be recommended except in cases of necessity. Another way is to melt the snow in the gauge by adding a measured quantity of warm water and subtracting this latter from the total quantity; the residue being entered as rain. It is best to try both plans. (Symons.)

† *E.g.* The total quantity of dew collected in England by Colonel Badgley in one year, by means of 'grass plates', was 1·6147 inches, the amount being measured with great accuracy. *v.* Nature, Vol. XLIII., p. 311. Of the whole annual precipitation at Munich dew gave 3·23 *per cent.* (Wollny).

‡ *v.* p. 317.

§ *Cf.* also what has been said before regarding humidity and cloudiness.

exceptions, *e.g.*, at parts of the Central Provinces south of the Satpura range, with an average rainfall not exceeding 50 inches, drought is almost unknown, whilst the North-West Provinces, with an average of 86 inches, have been visited not less than seven times during the present century with disastrous droughts.

Another point of great importance to sanitary engineers and others, to which attention has previously been drawn,* is the extraordinary difference there may be in the amount of rain received by two places situated comparatively near to one another. This is especially well seen in places which, though not distant from each other, vary in their geographical relation to neighbouring hills. An example of such a difference, given by Blandford, is the case of Baura Fort and Gokak. The former, situated on the crest of the Western Ghâts, has an average fall of 251 inches, the latter, at a lower level and sixty-five miles to the east; has an average of 22 inches. Enormous falls of rain sometimes take place in a few hours, amounting to 20—40 inches in twenty-four hours, and, curiously enough, these deluges may occur in places where the one fall of rain is more than three times the *average total* for the year!

The Average Annual Rainfall of the whole of India, exclusive of the mountain barrier (including Assam and Cachar) and Burmah, has been computed at 42 inches, but this enormous amount is very unevenly distributed, as the table from Blandford, given on the next page, will show.

The ordinary Seasonal Distribution of the rainfall in India may be roughly described in a few lines. In the spring there are slight showers at comparatively frequent intervals in Assam, Cachar and Lower Bengal, and in Southern India also three or four inches generally fall during the months of April and May—the so-called 'mango showers.' With the advent of the south-west monsoon the regular rainfall begins and continues from June to October.

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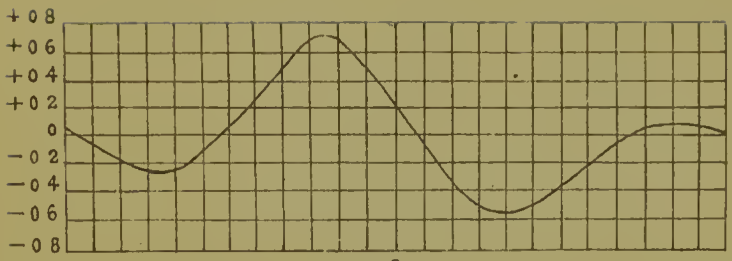
* *v.* pp. 48-9.

Plate XIX.



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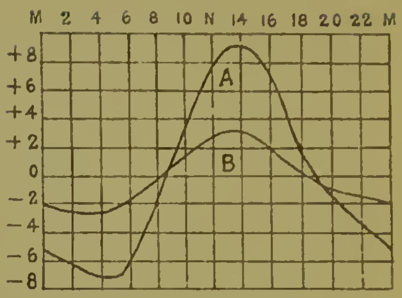
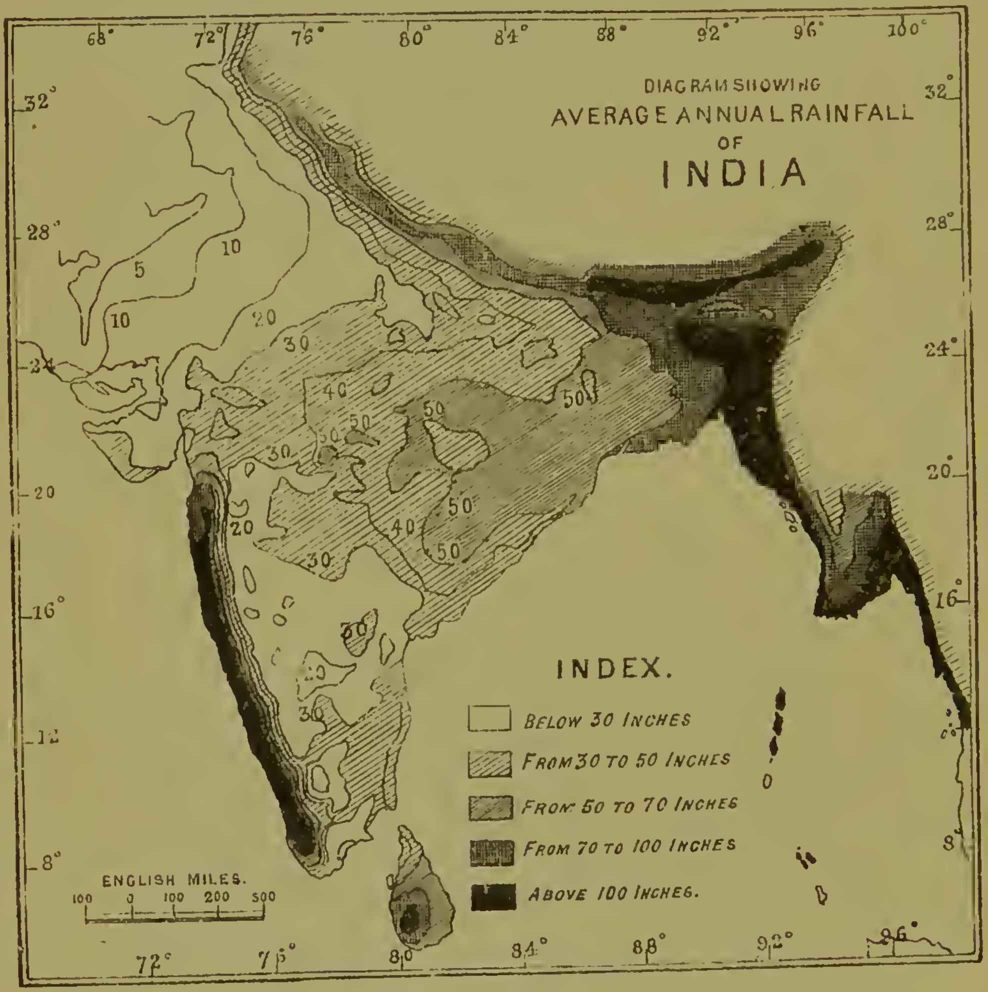
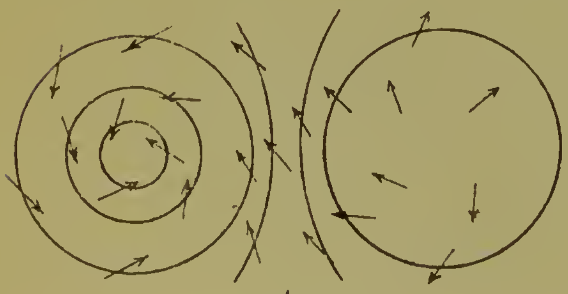


1.



3



4.

(a) 5. (b)

C. PACZENSKY LITH:

To face p. 330.

PLATE XIX.

RAINFALL, ETC. [AFTER BLANDFORD.]

Figure 1. To illustrate Diurnal Variation (*Fluctuation*) of the Temperature in India. Average Diurnal Curves, A. for March, B. for July, in Calcutta (*v*. p. 301).

Figure 2. To illustrate Diurnal Variation (*Fluctuation*) of the Atmospheric Pressure in India. Average Diurnal Curve for April, in Calcutta (*v*. p. 358).

Figure 3. Diagram of the Average Annual Rainfall of India.

Figure 4 Diagram of Cyclone and Anti-cyclone. "Let the right hand circle be supposed to represent a region where the barometer is highest, and the left hand circle that where it is lowest, the intermediate lines indicating a number of isobars of intermediate gradations of pressure. Then the winds that blow outwards from the region of high barometer, if in the northern hemisphere, instead of blowing directly outwards like the spokes of a wheel, all take an increasingly oblique course to the right of the radial direction, as shown by the arrows, and those that blow in towards the region of low barometer all blow obliquely to the right of that course which leads directly to the centre. The result is that the former describe a series of spirals curving round the seat of high barometer in the same direction as the movement of the clock hands; the latter, a series of spirals circulating round the seat of low barometer against the direction of the clock. The latter represents the movements of the winds in a cyclone" [in the northern hemisphere]. "When, as in the case of the monsoons" [*v*. pl. xx.], "neither the seat of highest barometer nor that of lowest barometer is a circle or any other regular figure, the course of the winds is not in such regular spirals" as those shown in figures 4 and 5.

Figure 5. Diagram showing the Spiral Course of the Winds in a Cyclone, (a) in the Northern Hemisphere, *e.g.*, in the North of the Bay of Bengal, (b) in the same latitude in the Southern Hemisphere.

AVERAGE ANNUAL RAINFALL OF THE PROVINCES OF INDIA AND BURMAH.

Rainfall Provinces.	Area in Square Miles.	Number of Stations.	Average Rainfall. Inches	Local Variation. Inches.
Punjab Plains	120,000	29	22	6 to 36
N. W. Provinces and Oudh	83,500	45	36	25 ,, 50
Rajputana (Eastern only)	67,000	19	28	14 ,, 63†
Central India States*	91,000	21	42	32 ,, 55
Behar	30,000	14	43	39 ,, 48
Western Bengal, Chutia Nagpur, etc.	38,000	10	49	43 ,, 61
Lower Bengal	54,000	29	66	54 ,, 112
Assam and Cachar	61,000	17	94	69 ,, 475†
Orissa and Northern Circars.	27,000	16	47	31 ,, 70
Central Provinces, South	61,000	19	51	43 ,, 79†
Berar and Khandesh	43,000	11	35	21 ,, 69†
Guzerat	54,500	14	33	18 ,, 47
Sind and Cutch.	68,000	10	9	4 ,, 19
North Deccan	48,000	14	29	18 ,, 49
Konkan and Ghats	16,000	13	141	74 ,, 261†
Malabar and Ghats	18,000	8	114	74 ,, 132
Hyderabad	74,000	19	32	23 ,, 43
Mysore and Bellary	58,000	17	29	18 ,, 36
Carnatic	72,000	40	36	20 ,, 62†
Arakan	11,000	6	156	105 ,, 214
Pegu	32,500	7	73	46 ,, 123
Tenasserim	10,500	4	171	142 ,, 196

This is the 'rainy season' for the whole of India save the south-east which only receives occasional showers. Later, when "north-east winds are beginning to blow in the north-west of the Bay, and both the incipient north-east monsoon and the residue of the southerly current are drawn towards the Carnatic and the southern half of the Bay," the heavy rain begins to fall in these latter places and continues to do so as long as the so-called north-east monsoon lasts. There is thus no time of the year when rain does not fall in some part of India.

There are many other points of extreme interest in connection with the rainfall of India, for details of which

* Including Jhansi, Saugor and Damoh, and the Nerbudda valley.
† In these cases one or more hill stations have a much higher rainfall than any at the lower levels.

Average Monthly Rainfall of Eighty Stations in India, Ceylon, and Burmah.

Stations.	Elevation in Feet.	Rainfall in Inches.												
		Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Kurrachee	49	0·6	0·3	0·2	0·2	0·1	0·2	3·1	1·8	0·9	0·1	0·1	0·2	7·8
Hyderabad	66	0·2	0·1	0·1	0·2	0·1	0·4	2·8	3·2	0·8	...	0·1	...	8·0
Quetta	5,501	1·6	1·9	2·4	1·3	0·5	0·1	0·8	0·6	0·2	0·1	...	0·4	9·9
Jacobabad	186	0·2	0·2	0·3	0·2	0·1	0·1	1·4	1·4	0·3	...	0·1	0·1	4·4
Mooltan	420	0·4	0·3	0·5	0·3	0·5	0·4	2·2	1·3	0·8	0·1	0·1	0·3	7·2
D. I. Khan	573	0·4	0·7	0·9	0·8	0·4	0·6	1·8	1·6	0·6	0·1	0·1	0·3	8·3
Leh	11,503	0·2	0·2	0·2	0·1	0·1	0·2	0·5	0·4	0·2	0·5	...	0·1	2·7
Peshawar	1,110	1·6	1·2	1·8	2·0	0·7	0·3	1·7	2·0	0·8	0·2	0·6	0·6	13·5
Rawalpindi	1,652	2·4	2·0	1·9	2·3	1·6	1·7	7·4	7·3	3·2	0·6	0·9	1·1	32·4
Murree	6,344	2·8	3·4	3·7	4·3	3·8	2·4	11·0	14·0	6·1	2·2	1·7	1·2	56·6
Sialkot	829	1·4	1·8	1·9	1·6	1·2	3·2	11·6	9·1	3·2	0·6	0·4	0·8	36·8
Lahore	732	0·7	1·1	1·1	0·6	0·9	1·8	7·4	4·6	2·4	0·6	0·2	0·5	21·9
Umballa	902	1·4	1·5	1·1	0·6	1·0	4·0	11·6	8·6	4·1	0·6	0·2	0·7	35·4
Simla	6,953	2·8	2·7	3·0	2·8	4·7	7·9	19·3	18·1	6·0	1·4	0·3	1·1	70·1
Delhi	718	1·0	0·5	0·7	0·4	0·7	3·4	8·5	6·9	4·5	0·5	0·1	0·4	27·6
Roorkee	887	2·0	1·4	1·0	0·4	1·2	5·1	12·5	12·3	5·1	0·6	0·2	0·4	42·2
Meerut	737	1·0	0·7	0·7	0·4	0·8	3·6	9·2	7·2	4·0	0·5	0·1	0·3	28·5
Agra	555	0·5	0·3	0·2	0·2	0·7	2·9	9·8	6·7	4·3	0·4	...	0·2	26·2
Deesa	465	0·1	0·2	0·1	0·1	0·2	2·2	9·8	8·5	3·3	0·8	0·1	...	25·5
Abu	3,945	0·2	0·4	0·1	...	1·0	5·1	22·2	22·5	9·1	2·1	0·2	0·2	63·1
Jodhpur	1,274	0·3	0·2	...	0·1	0·6	1·3	3·6	5·2	2·3	0·2	0·1	0·1	14·0
Neemuch	1,639	0·1	0·2	0·1	0·1	0·5	3·9	11·2	10·4	5·5	1·0	...	0·2	33·2
Indore	1,822	0·4	0·3	...	0·1	0·6	6·8	10·4	7·8	8·1	1·2	0·2	0·2	36·1

Ajmere . .	1,611	0·2	0·3	0·4	0·1	0·7	2·5	6·9	7·3	3·4	0·3	0·1	0·3	22·5
Jhansi . .	855	0·5	0·2	0·4	0·1	0·3	4·0	13·6	10·5	5·2	0·8	...	0·2	35·8
Lucknow . .	369	0·8	0·3	0·3	0·1	0·9	5·0	10·8	10·4	7·1	1·4	...	0·5	37·6
Allahabad . .	307	0·8	0·4	0·4	0·2	0·3	4·6	11·9	9·6	6·7	2·3	0·2	0·2	37·6
Benaras . .	267	0·7	0·5	0·4	0·2	0·5	5·0	12·8	10·7	6·5	2·1	0·1	0·1	39·6
Gorakhpur . .	256	0·7	0·5	0·4	0·3	1·5	7·7	13·3	11·8	8·8	3·0	0·2	0·1	48·3
Patna . .	179	0·7	0·5	0·3	0·3	1·6	7·1	11·0	10·1	7·9	2·9	0·2	0·2	42·8
Darjiling . .	6,912	0·7	1·2	2·4	3·7	7·1	24·1	30·5	26·0	17·8	6·4	0·2	0·2	120·3
Jalpaiguri . .	270	0·4	0·4	1·7	3·7	11·2	28·6	26·3	25·9	24·3	5·5	0·1	0·1	128·2
Hazaribagh. .	2,010	0·4	0·8	0·7	0·4	1·6	8·3	12·6	12·7	8·0	3·4	0·3	0·2	49·4
Bhagulpore. .	159	0·5	0·7	0·4	0·8	2·5	8·3	11·2	10·7	7·8	4·1	0·2	0·1	47·3
Berhampore .	66	0·4	1·0	1·0	1·9	4·8	9·7	10·3	10·8	9·8	5·3	0·3	0·1	55·4
Calcutta . .	18	0·4	1·0	1·3	2·3	5·6	11·8	13·0	13·9	10·0	5·4	0·6	0·3	65·5
Dacca . .	15	0·3	1·1	2·5	5·8	9·2	13·8	12·8	12·4	10·2	5·2	0·7	0·2	73·7
Chittagong . .	87	0·4	1·2	1·9	4·6	9·2	23·8	22·2	20·5	14·1	5·7	1·6	0·6	105·8
Silchar . .	87	0·6	2·6	7·9	13·0	15·7	19·1	20·6	18·2	14·2	6·4	1·0	0·7	120·0
Charrapunji .	4,455	0·6	2·6	9·0	29·6	50·0	110·0	120·5	78·9	57·1	13·6	1·8	0·3	474·0
Gauhati . .	370	0·6	0·9	2·5	5·8	10·1	12·9	12·7	11·2	8·1	3·1	0·6	0·3	68·8
Sibsagar . .	333	1·1	2·2	4·4	9·9	11·1	14·1	15·6	16·0	11·7	5·2	1·3	0·6	93·1
Cuttack , .	80	0·4	0·6	1·1	1·5	3·2	10·7	12·6	11·2	9·8	5·8	1·0	0·5	58·4
Samblapur . .	451	0·6	0·6	0·7	0·5	1·6	13·0	17·7	15·2	8·7	2·4	0·3	0·4	61·7
Saugor . .	1,769	0·6	0·5	0·2	0·2	0·6	6·3	16·8	11·2	7·3	1·3	0·4	0·7	46·1
Jubbulpore . .	1,351	0·6	0·5	0·5	0·2	0·5	8·5	18·6	13·8	8·2	1·5	0·4	0·3	53·6
Pachmarhi . .	3,504	0·5	0·3	0·4	0·3	0·6	10·8	28·8	18·2	15·1	1·9	0·4	0·7	78·0
Nagpur . .	1,025	0·6	0·4	0·6	0·5	0·8	8·8	13·3	8·9	7·8	2·3	0·4	0·5	44·9
Amraoti . .	1,213	0·5	0·2	0·3	0·2	0·6	6·9	8·8	7·0	5·3	1·6	0·2	0·6	32·2
Dhulia . .	1,000	0·3	0·1	...	...	0·4	4·8	4·8	4·0	4·6	2·0	0·5	0·4	21·9
Poona . .	1,819	0·2	...	0·2	0·6	1·6	5·6	6·6	4·1	4·3	4·1	0·8	0·2	28·3
Bombay . .	37	0·1	...	...	...	0·5	20·8	24·7	15·1	10·8	1·8	0·5	0·1	74·4
Matheran . .	2,200	0·1	...	...	...	0·8	35·7	84·4	50·7	31·0	5·3	0·6	0·1	208·7
Mahableshwar .	4,540	0·4	0·1	0·4	0·9	1·4	47·3	102·1	68·6	32·9	5·8	1·1	0·4	261·4
Karwar . .	44	0·2	...	0·1	0·3	2·9	34·5	37·7	21·7	12·0	5·2	1·7	0·2	116·5
Belgaum . .	2,550	0·1	...	0·5	2·0	2·8	9·3	15·2	9·0	3·7	4·7	1·2	0·3	48·8

Average Monthly Rainfall of Eighty Stations in India, Ceylon, and Burmah—Contd.

Stations.	Elevation in Feet.	Rainfall in Inches.												
		Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Jalna	...	0·1	...	0·1	0·1	0·8	7·2	6·8	5·3	7·5	3·4	0·8	1·4	33·5
Sholapur	1,819	...	0·1	0·3	0·7	1·2	4·6	4·3	6·0	7·5	3·7	0·7	0·4	29·5
Secunderabad	1,787	0·3	0·2	0·7	0·7	1·4	3·7	6·0	5·7	5·2	3·3	0·8	0·3	28·3
Bellary	1,455	0·1	...	0·6	0·8	1·8	1·8	1·3	2·3	3·7	3·9	1·0	0·3	17·6
Bangalore	2,981	0·2	0·1	0·6	1·3	5·0	3·2	4·0	5·9	6·3	6·4	1·9	0·7	35·6
Wellington	6,200	0·8	0·3	2·0	2·9	4·1	3·6	3·2	4·0	4·7	9·8	8·5	4·1	48·0
Bimlipatam	30	0·3	0·5	0·2	0·2	2·0	3·2	3·6	4·4	6·3	8·1	2·5	1·3	32·6
Masulipatam	10	0·3	0·1	0·3	0·1	1·7	4·4	5·6	6·0	6·5	8·8	4·0	0·7	38·5
Rajamundry	68	0·2	0·3	0·3	0·9	3·3	4·5	7·2	6·6	7·1	6·5	1·7	0·2	38·8
Cuddapah	477	0·1	...	0·2	0·3	1·6	2·6	3·5	5·1	5·8	5·3	3·1	0·7	28·3
Madras*	22	0·9	0·3	0·4	0·6	2·1	2·1	3·9	4·6	4·8	10·5	13·5	5·3	49·0
Trichinopoly	275	1·0	0·5	0·7	1·8	3·8	1·3	2·2	4·4	5·3	7·8	5·2	3·1	37·1
Cuddalore	20	1·0	0·3	0·4	0·9	1·5	1·4	2·3	5·1	4·7	8·1	14·1	5·7	45·5
Madura	448	0·7	0·4	0·6	2·0	2·8	1·6	1·7	4·7	4·5	8·7	5·1	2·2	35·0
Mangalore	52	0·2	0·1	0·1	2·0	8·1	37·8	37·9	23·1	11·3	8·0	1·9	0·5	131·0
Cochin	11	0·9	0·7	2·1	4·4	12·7	30·7	22·7	12·4	9·4	12·1	5·1	1·9	115·1
Trincomalee	175	6·2	2·4	1·3	1·6	2·2	1·9	2·2	4·2	4·6	8·9	13·1	13·2	61·8
Colombo	40	3·0	1·7	5·5	8·8	13·2	8·2	5·5	4·5	4·9	12·9	12·7	6·4	87·3
Galle	48	4·4	3·3	4·7	8·7	11·6	8·2	5·7	5·3	7·6	13·0	11·5	6·7	90·7
Rangoon	41	0·2	0·1	0·1	1·8	10·9	18·4	21·3	18·6	16·0	8·1	3·4	0·1	99·0
Moulmein	94	...	0·1	0·1	3·0	19·7	38·4	43·9	43·0	30·3	8·4	1·5	0·1	188·5
Thyet Myo	134	...	...	0·1	0·7	5·3	7·9	8·0	8·5	7·8	4·9	2·3	...	45·5
Tounghoo	169	...	0·2	...	1·5	6·6	13·4	17·5	18·1	11·8	7·4	1·4	0·2	78·1
Akyab	15	0·1	0·2	0·5	1·6	12·2	51·6	51·0	38·6	23·0	12·4	3·9	0·6	195·7

* Average for 80 years. C. Michie Smith.

special works must be consulted.* Attention must be directed, however, to the peculiar character of tropical rainfall as illustrated in India, *viz.*, its 'heaviness,' whereby the average fall of each rainy day at some stations is between 0·6 and 0·7 of an inch as compared with about 0·1 in climates like Great Britain. "In consequence," says Blandford, "of this character of Indian, in common with tropical rainfall generally, it is less penetrating in proportion to its quantity than in countries where much of it falls in a state of fine division, allowing time for its absorption by the ground. Instead of feeding perennial springs, and nourishing an absorbent cushion of green herbage, the greater part flows off the surface and fills the dry beds of drains and watercourses with temporary torrents. In uncultivated tracts, where jungle fires have destroyed the withered grass and bushy undergrowth, and have laid bare the soil and hardened its surface, this action is greatly enhanced; and while all perennial water supplies which depend on the absorbed rain are either greatly reduced or altogether suppressed, a rainfall which, if husbanded by nature and art, would suffice for the agricultural and domestic requirements of the population, is thrown into the nullahs and rivers, and not only is wasted and lost for any useful purpose, but by producing floods, becomes an agent of destruction. Under any circumstances, the character of the rainfall is hardly compatible with its economical storage and expenditure in any high degree: much more, therefore, than in temperate regions, is it incumbent on us to safeguard such provident arrangements as nature has furnished for the purpose."

SNOW AND HAIL.

When water vapour in the atmosphere becomes condensed at a temperature below freezing point it forms spicules of ice which may ultimately reach the earth as snow. The original ice-spicules combine to form snow

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* Blandford, *opera cit.*; also, Indian Meteorological Memoirs, vol. III. "The Rainfall of India," and various other meteorological papers.

crystals, usually six-rayed, and these crystals becoming felted together form snow-flakes. Snow never falls save on the hills in Northern India. The snow-line is about 14,000 feet but snow may fall in abundance at a lower level, *e.g.*, Simla, 7,048 feet. In such a case, however, it soon melts, whilst above the snow-line there is always snow. In colour snow is really bluish, but as ordinarily seen appears white owing to the reflection and refraction of light by the myriads of crystals. Under great pressure it may become compacted into solid ice. One foot of freshly-fallen snow is said to be about equivalent to one inch of rain, a very rough approximation.

Hail is a term applied to two different phenomena. True hailstones consist of pieces of ice which may vary in size from minute pellets up to large masses weighing several pounds. A section of such a hailstone generally shews alternate layers of clear ice and compacted snow.* It is said by some to be formed by a soft hailstone, as described below, which originally comes from a great height, falling into a rain cloud from which it receives a coating of water, and is thereafter carried back by an ascending air current into higher regions where the water becomes frozen into clear ice: this process of alternate ascent and descent being repeated several times till finally the stones fall to the earth's surface as a shower of hail. In the tropics, there are sometimes terrific hailstorms, the stones being of sufficient size to inflict great injury.† Hailstorms are commoner at hill stations than on the plains, but are not so destructive as a rule, the usual size of the hailstones being that of small marbles.‡

The other form of hail is known as soft hail, and looks like small snow balls about the size of a pea. Its origin is

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* *v.* illustration in *Nature*, 27th July 1893, p. 294.

† *E.g.*, Murree was this year (1893) visited on the 28th May by a storm of this nature. The hailstones were described as being the size of racquet balls, or about 1 inch in diameter, and are said to have rebounded from the ground to a height of several feet. Much damage was done to property. There are many worse storms than this on record. *v.* also Blandford's Ind. Met. *Vade Mecum*, p. 232, *et seq.*

‡ *v.* Blandford.

uncertain but it appears to be formed by the "larger ice particles in a deep ice cloud overtaking and adhering to the smaller ones."* It sometimes falls on the hills in India; never on the plains. It is common in climates like that of Great Britain during cold dry weather in winter, whilst true hail falls there only in summer.†

Influence of Snow and Hail upon Health.—The only point of any importance in this relation is the part played by snow in cold climates. Loosely compacted snow, as when newly-fallen, contains in its meshes a very large amount of air: the snowy covering thus acts as an excellent non-conductor of heat, by which radiation from the ground at night is obstructed and the earth prevented from freezing. Such an action is of extreme value in preventing the destruction of the young crops of wheat, etc., which are sown just before the winter season in Great Britain.‡ In very cold climates, such as in parts of North America, advantage is frequently taken of such a protective covering by persons who are overtaken by a storm. With their hands they scoop out a hollow in the snow big enough for them to lie in and, having covered themselves with snow, are thus able to avert otherwise certain death from cold.

Estimation of Snow and Hail.—Already described under Rain, in the previous section.

Snow and Hail in India.—Any further details than those given above would be foreign to the scope of this book and must be sought for in special works.

ATMOSPHERIC PRESSURE.

It is necessary at the outset to distinguish carefully between the *pressure* and *weight* of the atmosphere, the former being that with which alone we are here concerned. It is only when the air is at perfect rest and undergoing

* Mill, *op. cit.* *Cf.* formation of rain-drops, p. 325.

† The term 'Sleet' is applied to a mixture of snow and rain. It is unknown in the tropics.

‡ There are few more striking sights than the carpet of tender green shoots which is seen to cover a field after the melting of snow, the earth being bare and free from vegetation before the fall of the snow.

no change of temperature that the pressure and weight are equal, and this is a condition never completely fulfilled; so that it may be said truly that we "know nothing accurately of the weight of the atmosphere, but only that it cannot be very different from the average pressure."* In reality the atmosphere is continually in motion, upwards or downwards, and undergoing contraction or expansion, whence it follows that the height of the barometric column, as explained afterwards, though "always a measure of the pressure of the air acting on it, is no longer an exact measure of its weight."†

The following explanation may help the student to understand clearly the meaning of the term pressure as used in hydrostatics generally. Take a book measuring 6″ × 5″ and place it flat on the table. On the top of the book let a weight of 60lbs. be placed and evenly distributed over the cover. Then across any page of the book there will be equal and opposite forces acting, which tend to bring the two parts of the book on either side of the page closer together. We may express any one of these forces either as a force simply, *viz.*, 60lbs., or as a force per unit area of the page, *viz.*, 2lbs. per square inch. The former denotes the total thrust across the page, the latter denotes the pressure. *Pressure*, then, is the *thrust per unit area.*

Now take the case of heavy fluids at rest. They exert a force or thrust across any surface with which they are in contact and this thrust is always perpendicular to the surface. Suppose a plane area, of a square inches, immersed horizontally in a heavy fluid at rest. The fluid will exert a force of, say, P lbs. across either face of this area. Over the area, then, or at any point in the area the pressure is $\frac{P}{a}$lbs. per square inch. Now, the following propositions hold in the case of heavy fluids of uniform density, at rest.

(i) That the pressure is the same at all points in the same horizontal plane.

(ii) That the pressure increases uniformly with increase of depth below the free surface.

That air is a heavy fluid was first proved by Otto Guericke. The same is true of gases generally. Consider, then, a mass of gas contained in a closed vessel. Strictly speaking, the pressures at different points not in the same horizontal plane are not equal. If, however, the dimensions of the vessel are not very large, this difference will be very small and can be neglected. The pressure at all points will thus be equal and its value is called the *pressure of the gas.* This pressure is due, not to the weight of the gas, but to the *mass and motion of its molecules.* The molecules of a gas are constantly moving about with very large velocities on the average. If the gas is confined in a box, the molecules will be continually impinging on and rebounding from the sides. It is the blows thus given to the sides that cause the pressure.

In the year 1643, Torricelli, a pupil of Galileo, proved

* Blandford. † *Ibid.*

by a simple experiment that the atmosphere exerts a certain pressure upon all objects. He knew from experience that if he took a tube open at both ends and, having plunged the lower end into a trough containing mercury, poured mercury into the upper end, the mercury would, by its own weight, run out through the lower end as fast as he poured it into the upper end. So he took a glass tube about 33 inches long and closed at the top, and, having filled it with mercury, he inverted it and plunged the lower end into the mercury in the trough. As a result he found that the mercury within the tube sank slowly till it stood almost exactly 30 inches above the level of the mercury in the trough and then ceased to fall.

From what has been said above it is evident that in such an experiment every point at the surface of the mercury must be at the same pressure, the only difference being that the mercury in the trough, but outside the tube, is subject to the pressure of the atmosphere, whilst that immediately under the tube is subject to the pressure exerted by the column of mercury within the tube, but not to the pressure of the atmosphere. Thus it is clear that the pressure exerted by the atmosphere on a given area is equal to the pressure* of about 30 inches of mercury, or 14·75 pounds *per* square inch.

Another way of proving the existence of this pressure is to take such a tube and, having exhausted it of air as completely as possible, to invert it as before in a basin of mercury. The fluid will at once enter the tube from below and continue to rise till it stands at about 30 inches above the level of the mercury in the basin, or in other words, until the pressures exerted by the atmosphere and by the fluid in the tube have been equalised. The actual height of the column of liquid which is 'supported' by the atmospheric pressure depends mainly upon the specific gravity of the liquid of which the column is composed. Therefore, if water is used instead of mercury the column

* or *weight*, for in this case they are the same.

of liquid will be about 34 feet instead of 30 inches. The principle of the common pump is simply the partial exhaustion by suction of the air in a closed tube, the lower end of which is inverted in water, so that on the pressure of the atmosphere being removed, the water rushes up the tube and is discharged.

Soon after Torricelli had made his discovery and furnished the explanation, a practical demonstration of the correctness of his theory was given by Pascal and his brother-in-law Perrier. The former argued that if Torricelli's explanation was the true one, then the column of mercury would stand at a lower level if the experiment was repeated at the top of a mountain, owing to the diminution in the depth of the atmospheric strata above the mercury and consequent lessening of the pressure. Accordingly, Perrier ascended a mountain about 3,500 feet high and, having repeated the experiment, ascertained that the column stood at about 26 instead of 30 inches, at that elevation. Since that time the pressure of the air has been constantly measured by means of an instrument constructed on this principle, which has received the name of barometer, and which may also be used, with certain precautions described afterwards, to measure the height of any place above sea level.

It was discovered by Dalton that a space filled with any gas or vapour is as a vacuum to any other gas or vapour. There is thus surrounding the globe an atmosphere of nitrogen, which exerts its own pressure upon the earth's surface, an atmosphere of oxygen, which exerts about one quarter of the pressure exerted by the former, an atmosphere of carbonic acid, small in amount and exerting but a slight pressure and, finally, an atmosphere of water vapour; all of which together make up the total atmospheric pressure. Of these, the water vapour is the most variable at any one part of the atmosphere, is that which differs most at different parts and, consequently, is that which is most influential in producing changes of pressure.

It was formerly assumed, and acted upon in reducing barometric observations, that the "pressure or tension of the water vapour in the air could be deducted from the total pressure and that the balance would be the pressure of dry air." This, however, has been shown to be a mistake. Hence, owing to the distribution of temperature, whereby the upper atmospheric strata are practically always cooler than those below, and to the fact that the water vapour by its friction communicates its pressure to the dry air with which it is intermingled, "although the separation of the pressures may indicate the proportions in which air and vapour contribute to the total pressure around the cistern of the barometer, the distinction has only a local meaning, and does not apply to the great mass of the superincumbent atmosphere."*

Attention has already been drawn to the fact that owing to its compressibility about one-half of the atmosphere lies between the earth's surface and a height of 15,500 feet, so that at the latter height the barometer stands at about 15 inches. At double this height, 37,000 feet,† the mercury would stand at 7 inches, and so on, till at 21 miles the mercury would stand at 0·5 inch. If Boyle's law‡ held good indefinitely, the atmosphere would have no definite limit. "It has however been proved that this law does not hold for gases of very small density, which behave like very light liquids and have a definite surface, so that the atmosphere has an upper limit beyond which the particles of gas do not stray.§

Changes in atmospheric pressure are mainly due to the effects of heat, but they are also brought about, especially indirectly, by the agency of water vapour. The great

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* Blandford. v. Ind. Met. *vade mecum*, pp. 108—10 for fuller explanation.

† Reached by Mr. Glaisher in his memorable balloon ascent from Wolverhampton in England, 5th September, 1862. At a height of over 29,000 feet, Mr. Glaisher noted a reading of 9·75 inches, and became unconscious soon afterwards. His partner, Mr. Coxwell, believed that he saw the mercury standing at 7 inches, before the descent began.

‡ *The density of any gas is proportional to the pressure it supports.*

§ Mill, *op. cit.*, p. 101.

annual variations of pressure are easily traceable to the effect of the position of the sun's maximum heating effect varying with the season, but the causes of the minor and more local variations are less easy to trace. The important depressions which, in the tropics, give rise to cyclones are probably due, primarily, to excessive local heating of the air by the sun in a region well supplied with moisture. The effect of this is to produce an upward flow of air and, as has already been explained, this air cools as it ascends and part of the moisture condenses as rain. But, when the moisture condenses, heat is liberated which prevents the air cooling to the extent it would otherwise do, and so the upward current, instead of ceasing as it would do in dry air, continues and, if the supply of moisture is sufficient, becomes intensified, the barometric depression is increased, and a violent cyclone may be formed.

When we come to study the effects produced upon the human organism by changes in pressure, it is found that the subject has to be considered under three aspects, analogous to those under which temperature changes in their relation to health have been already discussed,* *viz.*, (1) the effect of a *sudden change* from a relatively low degree to a high degree of pressure and *vice versâ*; (2) the effect of a *gradual lessening* of the pressure; and (3) the effect of a *gradual raising* of the pressure.

Effects of rapid changes in pressure.—The human body, as is well known, is marvellously adaptable to changed conditions, provided that the changes are made at a reasonably slow rate. Conversely, when one or more important conditions to its vitality are suddenly and materially altered there is great risk of a shock fatal to the organism being sustained. Now the extreme variations in atmospheric pressure which take place at or near sea level amount to but a few inches rise or fall of the barometric column, such rise or fall occurring only within limits consistent with perfect health. But there are three chief occasions

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* *v.* p. 289.

when human beings are liable to be subjected to sudden and violent alterations in pressure, *viz.*, in balloon ascents, in working under water in closed pneumatic chambers or *caissons,* and when working as divers at the bottom of the sea, either naked or clothed in a special dress or 'diving bell' communicating with the air by means of tubes. In balloon ascents, as noted before,* the pressure may be very rapidly lessened by as much as ten to twenty inches, and such lessening produces very serious and even fatal effects upon those who are exposed to it. In the case of men working in pneumatic tubes a wonderful increase of pressure can be borne with safety, *when gradual,* but if the pressure in the caissons be too rapidly increased or decreased, most serious symptoms, ending in some cases in sudden death, are set up. The explanations of these fatal results, so far as known, will be given under the next two headings.

Effects of Increased Pressure.—It is obvious that miners and others working at a great depth below the surface of the ground, carry on their labour under a constant increase of pressure, but it has not been proved that such amount of increase has any appreciable effect on their health. If anything, it probably increases their muscular power which, however, is apt to be seriously interfered with indirectly by adverse conditions of foul air, dampness, etc.

In pneumatic tubes the pressure generally varies between 2·5 and 4·5 atmospheres, which is, of course, largely in excess of any pressure occurring naturally.† When the men are subjected to a gradual increase and decrease of

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* *v. f. note,* p. 341. In the ascent made by Messrs. Crocé-Spinelli, Sivel and Tissandier on 15th April, 1875, the balloon rose in two hours to about 26,000 feet and remained at 26,000—28,000 feet for two hours more. At the end of this period the two former were found suffocated with their mouths full of blood, and the sole survivor, M. Tissandier, became insensible.

† The pressure may be largely increased as a result of an accident in a coal mine, on board ship, etc., and many men may be confined in a small space. In one such instance, the air in a confined space in a coal mine was under sufficient pressure to drive a man out of the opening made by the relief party and kill him. The other men who had been shut up with him had suffered no serious inconvenience during their enforced captivity of several days, without food of any kind.

pressure on entering or leaving the tube no ill effects are observable. It is specially important that the return to a normal from a greatly increased pressure be slowly made; it should occupy twenty minutes to half-an-hour or longer. Divers also work under greatly increased pressures, and in their case there is the additional pressure due to water, which may amount to as much as 6 atmospheres. They are apt to suffer from pricking pains, hæmorrhages, tinnitus and deafness, etc., and in serious cases become paralysed, owing to extravasation of blood between the spinal cord and its membranes.

Therapeutically, compressed air has been tried in the form of 'compressed air baths' for various pulmonary complaints,* the apparatus consisting of a strong, circular chamber made of metal in which, after the patient is seated, the pressure can be raised to the desired extent by pumping in air. A pressure equivalent to an additional 0·4 to 0·6 atmosphere above the normal is generally employed. Besides minor symptoms, the following effects are produced upon the respiratory system. The frequency of the respirations falls to about twelve per minute, whilst the pulmonary capacity and the amplitude of the respirations are increased. An extra quantity of oxygen is inhaled and the excretion of urea and carbonic acid is increased. It is further stated that if the patient is suffering from any pulmonary complaint attended with difficulty of breathing, there is marked improvement in the ease and quality of the respirations, particularly in the case of emphysema. Of course, in these cases the pressure is increased and lessened very gradually, about twenty minutes being allowed for each change. The chief physiological effect of increasing the pressure appears to be that the blood is driven inwards, so to speak, whereby the superficial parts become relatively bloodless whilst the internal organs are congested to a degree corresponding to the excess of the external pressure above the normal.

* *v.* Paper by Dr. C. Theodore Williams in B. M. J., 15th April, 1885.

Effects of Lessened Pressure.—The exact nature of the effects produced by a gradual lessening of the atmospheric pressure has been much disputed and so, for the purpose of settling the matter as far as possible, Mr. Whymper, the well known alpine climber undertook, about the year 1880, an arduous journey to the mountainous interior of Ecuador, in S. America, in order to see 'whether human life can be sustained at great altitudes above the level of the sea in such a manner as will permit of the accomplishment of useful work,' as opposed to the mere possibility of existence for a short time.*

The three points investigated were as follows :—(1) At what pressure were any unusual effects noticeable ; (2) What was the precise nature of these effects ; and (3) Was it possible to become habituated to these effects ? At a pressure of 16·500 inches (16,664 feet) the three explorers were quite incapacitated for work and found themselves 'preoccupied by the paramount necessity for obtaining air.' Special stress is laid on the fact that such incapacity for work was neither due to exhaustion nor to deficiency of bodily strength, nor to weakness from want of food, but was caused by the whole attention being taken up in efforts to get enough air. The attack was very sudden, the chief symptoms being laboured and gasping respiration, intense head-ache and an 'indescribable feeling of illness' throughout the whole body : in addition, there was feverishness and a marked acceleration of the pulse. The attack gradually passed off. Mr. Whymper concludes that his party became *somewhat habituated* to low pressures, as evidenced by an improved rate of speed during the later journeys.† He finds, however, that the

* "The most opposite statements and opinions have been advanced concerning this matter. The extremes range from saying that fatal results may occur, and have occurred, from some obscure cause, at comparatively moderate elevations, down to that no effects whatever have been experienced at the greatest heights which have been attained." *Travels Amongst the Great Andes of The Equator*, Whymper. The original work is full of interest and should be read by all concerned with this important question.

† It is noteworthy that an extra member of the party, who was with

rate of progress is materially affected at a pressure of 21 inches (9,850 feet), a fact which must affect 'all calculations which may be made on the basis of higher pressures either in respect to the marching of troops, transport of animals, the labour of the navvy, or any other description of muscular exertion.'

He divides the effects produced into two classes:—(1) *transitory*, and (2) *permanent*. Under the former head come increased pulse-rate, increased body temperature, and pressure on the blood vessels [rise in blood pressure?]: under the latter, increase in frequency and altered character of the respirations, loss of appetite and loss of muscular power. The Temporary symptoms he ascribes very reasonably to the expansion of gaseous matter within the body, the result of diminished external pressure, these symptoms dying away on the establishment of equilibrium between the internal and external pressure.* From the Permanent effects, the direct result, no doubt, of the rarefaction of the air, there is no escape. At a pressure of 14·750 inches (19,600 feet) it is possible to sustain life while at rest, by breathing through the wide-opened mouth, but any attempt at movement, entailing a further demand for air, makes it almost impossible to breathe at all.

At lower elevations, such as 3,000—8,000 feet, between which extremes most Indian hill stations are situated, various temporary effects are noticeable;† but in the healthy these soon pass off and great exertion can be undergone

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them during their first attack and who had lived for many years in Ecuador, did not suffer at all. He did not ascend, however, above 17,000 feet. None of the party suffered at any time from the so-called *mal-de-montagnes* or mountain sickness, complained of by many travellers, and upon which great stress has been laid by some. For an account of the symptoms and other details of this supposed malady, and references to Indian literature on the subject, *v.* Hirsch, *Handbook of Geog. and Hist. Path.*, Vol. II., p. 503, *et. seq.*

* In the case of aeronauts the lessening of the pressure is so *rapid* that violent hæmorrhage, with suffocation, is apt to supervene and cause a fatal result.

† The most prominent is, naturally, 'want of breath' on first arrival. In some cases there is disorder of the cerebral circulation with giddiness, deficient accommodation, etc.

with pleasure and safety. Persons suffering from advanced heart disease* or from a liability to hæmorrhage from any of the mucous surfaces should on no account be permitted to ascend above 3,000 feet; for such, a sea voyage or a change to a colder climate is in every way more suitable.

The subject of the effects produced by lessened atmospheric pressure upon healthy and sick persons is by no means thoroughly elucidated as yet,† but it is of immense importance, both on account of the great elevation of some of the Indian sanitaria and because of the chance of future military operations on the N.-W. frontier being carried on at still greater altitudes.

Barometers.—As mentioned before, the instrument invariably used for measuring the atmospheric pressure at meteorological stations is known as the Barometer. There are two chief classes of barometer, the *mercurial* and *non-mercurial*, the former being much the more important. Every mercurial barometer is essentially a modification or adaptation of the tube and basin of mercury used by Torricelli in his famous experiment. In some cases a U-shaped tube is used, in which one leg is only about $\frac{1}{3}$ as long as the other and open at the end. There is, of course, a 'Torricellian vacuum' between the upper level of the mercury and the closed end of the long limb, the space so left containing nothing but a little vapour of mercury. As the pressure rises the mercury is depressed in the short limb and raised in the long limb, and *vice versâ*. Two readings must always be taken, *viz.*, the height of the mer-

* A case occurred not long ago at a hill station about 8,000 feet above sea level, in which a lady, newly arrived, suffered from almost continuous fainting fits on the smallest exertion, such as walking across a room, and was only kept alive by the constant administration of cardiac and other stimulants.

† A most elaborate series of experiments upon himself and other human beings and upon the lower animals, was carried out by the late Paul Bert, the distinguished French scientist. An account of these is given in his book *La Pression Barometrique*, a summary of which will be found under appendix J. in Mr. Whymper's book. He strongly recommended the carrying of oxygen for inhalation when at great heights. Hitherto its bulkiness has prevented this being done, but it is quite possible that it may some day be rendered easily portable in large quantity.

cury in both limbs. This form is known as the Siphon barometer and resembles the mercury manometers used in physiological experiments to measure blood pressure, etc. It is a good form of barometer, and is especially adapted for use in mountain ascents. Owing, however, to the necessity for a double reading it has been almost completely replaced by the instrument next to be described. When a siphon barometer has to be moved, the upper end is gently lowered so that the mercury in the long limb rises to the top and that in the short limb passes beyond the bend into the long limb. In this way air is prevented from passing up so long as the instrument is carried in the proper position.

The standard barometer on Fortin's principle is that now in general use in India. It consists essentially of a glass tube, about 34 inches in length, closed at the top and filled with pure mercury (spec. grav. 13·594). The lower end of the tube is open and dips into a cup containing mercury, the cistern. The tube is placed exactly vertical, so that the mercury stands at a height between 27 and 31 inches above the mercury in the cistern, according to the changes in the atmospheric pressure from time to time; the instrument being at or near sea level. The space above the mercury is a 'Torricellian vacuum' as in all ordinary barometers.

It is said above that the total length of the column is *measured** from the upper level of the mercury in the cistern and as, during changes in the mercury level in the tube, mercury must enter or leave the cistern it is obvious that the level of the mercury in the cistern undergoes changes related to those in the column. This may be compensated for (1) by a so-called 'capacity correction'; (2) by a pliable cistern base; (3) by a contracted scale; or (4) by dispensing with the use of a cistern altogether and employing a siphon barometer as previously described. Of these the second method is the most important for our purpose and is that invented by Fortin. By the use of a cistern, of which the bottom is formed of a bag of leather or of a

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* N. B. not *read*. *v.* p. 351, line 9.

solid, but movable, piston the cistern level is adjusted to a *constant point* which is the zero of the scale (Pl. xvi.) This constant point or zero of the scale is generally a pointed ivory stud, its tip being known as the *fiducial point*. To 'set' the barometer, before taking a reading, the level of the mercury in the cistern is adjusted by means of the thumb screw at the base till the fiducial point and its reflection in the mercury *exactly meet.*

The tube is mounted in a brass* case suspended vertically from a hook at the top of a mahogany board, whilst at the lower end of this board is a socket or ring with clamping screws to steady the barometer during the time a reading is being taken. To the front of the case a thermometer is attached.

The scale is engraved with great accuracy on the case, in inches and divisions of an inch, and attached to the case at its upper part is a movable dividing scale, controlled by a rack and pinion, and called, after its inventor, the *Vernier.* The principle of the Vernier scale is as follows. Each inch on the fixed scale engraved on the case is divided into tenths (0·1) and half-tenths or twentieths (0·05), and the Vernier scale is so divided that 25 of its divisions are equal to 24 of the smallest divisions on the larger scale. In other words, each vernier division is $\frac{24}{25}$ of these latter, *i.e.*, it is $\frac{1}{25}$ smaller. Now $\frac{1}{25}$ of $\frac{1}{20} = \frac{1}{500}$ or 0·002 inch and this is the value of each of the smaller divisions on the vernier scale. For convenience sake, however, there are engraved upon it at proper intervals, larger divisions corresponding to $\frac{1}{100}$ or 0·01 inch. Thus the fixed scale and the vernier are usually graduated as follows :—

Every long line	cut on the barometer scale corresponds to	a tenth	(0·100) of an inch
,, short ,,		,, five hundredth	(0·050) ,,
Every long line	cut on the vernier scale corresponds to	,, one hundredth	(0·010) ,,
,, short ,,		,, two thousandth	(0·002) ,,

* "Brass is considered the best material, because its coefficient of expansion by heat is well known ; and this is very important, as the tables for correcting barometer readings for temperature, founded upon the coefficients of expansion of mercury, glass, and brass, always give identical results with such barometers, although the nature of the alloy forming the cases may not in all instances be exactly similar." *Official Instructions in the use of Meteorological Instruments*, Scott.

By such an arrangement the barometer can be read accurately to 0·002 of an inch.

In reading the vernier the two primary essentials are that the barometer shall hang vertically and be placed in a good light. The milled head of the pinion is turned till the *lower* edges* of the vernier are exactly on a level with the convex top of the column of mercury, so that the front edge of the vernier, the *middle* and *uppermost* point of the column and the back edge of the vernier are on the line of sight.† The eye of the observer must also be exactly on a level with the top of the mercury column, otherwise the reading will be incorrect. If, when this has been done, the lowest line on the vernier exactly corresponds with one of the divisions on the fixed scale, the last line of the vernier will correspond also with another division, but none of the other divisions will so correspond, and the reading is made direct from the fixed scale and may be, *e.g.*, 29, 29·6 or 29·65 inches. If, on the other hand, *e.g.*, the eighteenth division on the vernier is the first to correspond exactly with a division on the fixed scale, then the fixed scale is read to tenths and five hundredths of an inch, say 29·650, and to this is added 0·002 × 18 = 0·036 inch‡; the actual reading of the barometer being thus 29·650 + 0·036 = 29·686 inches. It is thus evident that as the vernier divisions are followed upwards, 0·002 inch is lost for every vernier division as compared with the divisions on the fixed scale, till the fractional excess of the mercury column above 29·650 inches has been lost;

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* In some barometers the 25 divisions on the vernier correspond to 26 of the smaller divisions on the fixed scale, instead of 24, so that each vernier division is $\frac{1}{25}$ *larger* than the others. In this case the vernier is read downwards instead of upwards, from its own zero.

† If the vernier edge is brought too low, instead of being tangential to the column of mercury, it will correspond with a chord of the curve made by the convex surface of the mercury. The reading is much facilitated by a piece of white paper placed behind the tube so as to reflect the light, and at night by a candle held at the side, for as short a time as possible.

‡ *i.e.*, if the long lines on the vernier scale are disregarded. If these, each of which is equal to 0·01 inch, are counted, it will be found that there are 3 below the division containing the eighteenth short line. Add therefore, 0·01 × 3 = 0·03 to the reading on the scale, and then 0·002 × 3 = 0·006, *i.e.*, altogether, 29·650 + 0·030 + 0·006 = 29·686.

when the marks on the two scales must correspond. The above will be easily understood by a reference to the diagrams in plate xix. or, better still, by practising the reading of a barometer itself, if access can be had to one.

In making use of the barometer it is necessary (1) to set the instrument; (2) to read it; and (3) to apply certain corrections to the observed readings.

To set the barometer, (*a*) read the attached thermometer; (*b*) adjust the mercury in the cistern,* so that the fiducial point and its reflection exactly meet, forming a double cone; and (*c*) set the vernier. It is then read, the setting and reading being done as quickly as possible, to avoid heating of the instrument by proximity of the observer.

Before the records of any barometer can be accepted as trustworthy it is necessary to ascertain that the proper corrections have been applied. Some of these corrections have reference to the special instrument employed, whilst others are applicable to all instruments used under the same conditions. The corrections of the former class are three in number, *viz.*, (1) for *Index Error*, (2) for *Capacity*, and (3) for *Capillarity*. As before explained, in barometers constructed on Fortin's principle, the mercury in the cistern is adjusted at each observation to the *neutral point*, so that there is no 'capacity correction' to be applied to the reading.† So also for siphon barometers there is no capacity correction, a double reading being taken instead; neither is there any correction for capillarity, if both legs of the siphon have the same diameter.‡

In a Fortin's barometer the 'index correction,' resulting from error in graduation, and the 'capillarity correction,' arising from the capillary action of the glass tube upon the mercury, are constant and are usually combined. The com-

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* The barometer being kept exactly vertical by means of the clamping screws mentioned on p. 349. It is well to tap the tube gently before setting the vernier, and at least three different settings should be made for each reading.

† *v.* p. 348. ‡ *v.* p. 347.

bined correction may be positive or negative, but is usually negative.* These errors are ascertained by comparison with a standard barometer at Kew, Calcutta, etc.; the engraved scale being also compared with a standard scale.

The corrections applicable to the readings of all instruments are (*a*) for *Temperature*, (*b*) for *Altitude* above sea level. To a certain extent, a barometer acts like a thermometer, the mercurial column expanding (rising) or contracting (falling) with every rise or fall of the temperature. It is necessary, accordingly, to allow for this in comparing different barometric observations, and the difficulty is got over by applying to all readings a 'temperature correction,' whereby the reading is stated as if taken at a temperature of 32° F. That is to say, we subtract the increase in height of the mercurial column due to the difference between a reading taken at 32° F. and the observed temperature, say, 87° F. The correction is usually made by reference to special tables, but it can easily be applied from a formula. The necessity for applying a 'correction for altitude' is obvious from what has previously been said,† and, roughly speaking, the barometer reading falls about 0·001 inch for every foot above sea level.‡ All readings, then, taken at any station not more than 2,000 feet above sea level, are reduced to the value they would have at sea level and are so expressed. At places situated at a higher level than between 2,000 and 3,000 feet, and many Indian hill-stations are so situated, the pressure is that of a "stratum of the atmosphere, in which the relations of pressure are, at certain times, demonstrably different from those on the plains below. The reduced pressures of these stations are, therefore, not comparable with those observed on the plains."§

* The correction for index error may be positive or negative: the correction for capillarity is necessarily positive.

† *i.e.*, of course, when 'weather observations' are being made, in contradistinction to the calculation of the elevation by means of the fall in the mercury level.

‡ For the first 300 feet, when the air has a mean temperature of 90° F.; and by a greater amount for all lower temperatures. *v. post.* pp. 354-7.

§ Blanford. For further details as to the methods of applying these corrections, the works of Blandford and others must be consulted.

The only important non-mercurial form of barometer, and one which is extremely portable and very sensitive, is the Aneroid. This instrument consists essentially of a small, hermetically-sealed metallic box, exhausted of air as completely as possible, so that when the pressure of the atmosphere rises the top of the box is forced inwards, and when it falls the top is pushed outwards by means of a spring acting in opposition to the vacuum chamber. The changes in shape of the vacuum chamber are communicated by mechanism to a hand which indicates the increase or decrease in pressure on a graduated dial. These instruments do not, of course, indicate pressure absolutely and so have to be graduated experimentally. They are usually compensated for temperature by a special arrangement, and do not, therefore, require a temperature correction. Readings of the mercurial barometer, if compared with them, must first be reduced to 32° F. As a matter of fact, however, there is usually an error of some sort in the readings of an aneroid, and the instrument should be compared from time to time with a standard barometer.*

As with temperature, so with pressure, there are certain changes which are regular or *periodic* and others which are irregular or *non-periodic*, the former being known as *fluctuations*, and the latter as *undulations*. Thus, there is a diurnal fluctuation of the barometer in India, of a remarkably regular character. It is described later and is illustrated in plate XIX. There are also monthly and annual fluctuations. These periodic pressure changes bear a distinct relation to the temperature fluctuations before described.† The causes of the non-periodic changes are sometimes very easy and sometimes very difficult to trace. They are of extreme importance in connection with weather forecasts but do not specially concern us here.

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* For further information on the great precautions necessary to obtain anything like reliable readings from aneroid barometers under greatly varying pressures, v. *How to use the Aneroid Barometer*, by E. Whymper.

† v. pp. 299, 300.

Barometric *charts* are much used in connection with weather reports. In these charts places with the same pressure* are connected by lines indicating equal pressure and termed *isobars*. As a rule, the isobars show differences of 0·1 inch in the pressure. The space enclosed within an isobar of lowest pressure is termed a *barometric depression* or *minimum*, and that surrounded by an isobar of highest pressure is named a barometric *elevation* or *maximum*. The rate at which the pressure falls between any two places is termed the *barometric gradient*, and is usually expressed by the distance in which the pressure falls 0·1 inch.† In Indian charts, however, as will be afterwards explained, very slight variations in barometric readings are so important that isobars are given for differences of 0·05 inch. Its value in any case is easily ascertained by measuring to scale on a weather chart the number of miles between, *e.g.*, an isobar of 29·95 and 29·85, or any others where the difference is 0·1 or 0·05 inch. Where the distance is small and the isobars relatively near one another, the gradient is said to be *steep* and *vice versâ*. Isobars are therefore strictly comparable to the contour lines used by surveyors and others to indicate points of equal altitude, the contour lines being closely placed or distant according as the gradient of the intervening ground is steep or the reverse. Examples of barometric charts illustrating the above points will be found in plate XX.

The Calculation of Heights by Means of the Barometer.—Pressure diminishes as we ascend above sea-level because the quantity of air above us becomes less; but not uniformly, because the atmosphere is less dense in proportion to elevation. The greater the height above the sea the greater must be the number of feet to be ascended in order to produce a given depression of the mercurial column. These facts are illustrated by the following table, which affords a rough method of measuring heights. The differ-

* *i.e.*, after the local barometer reading has been corrected and reduced to sea level.

† Sometimes, by the decrease in pressure per 100 miles.

ence between reduced readings before and after ascent gives the depression; and the number of feet corresponding is corrected for temperature by multiplying it by

$1 + \frac{t + t' - 64}{900}$, t and t' being the temperatures of the points left and reached.

TABLE FOR ROUGH MEASUREMENT OF HEIGHTS.

Depression of Mercury in Inches.		Ascent in feet.
From	To	
31	30	857
30	29	886
29	28	918
28	27	951
27	26	986
26	25	1,025
25	24	1,068
24	23	1,113
23	22	1,161
22	21	1,216
21	20	1,276
20	19	1,341
19	18	1,413

As this method assumes that temperature and pressure remain constant at each point during the ascent, it is obviously unsuited to cases where accurate measurement is required. For this purpose precisely simultaneous readings of two good barometers, at the two points the difference between whose heights above sea level is to be ascertained, are desirable. If this is impracticable the barometer should be carefully compared before starting and after return with that in the nearest Meteorological Station, and the regular observations made at the latter compared with the traveller's. Besides noting the attached thermometer for reduction, the indications of an accurate thermometer freely exposed in the shade are to be

recorded.* If the places are only a few miles asunder, two or three readings are generally sufficient; if the interval be considerable, half-monthly means should be compared. From these data and the Table following differences in height can be calculated with almost absolute accuracy.

TABLE FOR CALCULATING HEIGHTS.

Barometer reduced.	Height in Feet.	Difference.	Barometer reduced.	Height in Feet.	Difference.	Barometer reduced.	Height in Feet.	Difference.
22·0	9,347	124	25·0	5,863	109	28·0	2,774	97
22·1	9,223	123	25·1	5,754	108	28·1	2,677	97
22·2	9,100	122	25·2	5,646	108	28·2	2,580	96
22·3	8,978	122	25·3	5,538	108	28·3	2,484	96
22·4	8,856	122	25·4	5,430	107	28·4	2,388	96
22·5	8,734	120	25·5	5,323	106	28·5	2,292	96
22·6	8,614	120	25·6	5,217	106	28·6	2,196	95
22·7	8,494	120	25·7	5,111	106	28·7	2,101	95
22·8	8,374	119	25·8	5,005	106	28·8	2,006	94
22·9	8,255	119	25·9	4,899	105	28·9	1,912	94
23·0	8,136	118	26·0	4,794	105	29·0	1,818	94
23·1	8,018	118	26·1	4,689	104	29·1	1,724	94
23·2	7,900	117	26·2	4,585	104	29·2	1,630	93
23·3	7,783	117	26·3	4,481	103	29·3	1,537	93
23·4	7,666	116	26·4	4,378	103	29·4	1,444	92
23·5	7,550	116	26·5	4,275	103	29·5	1,352	92
23·6	7,434	115	26·6	4,172	102	29·6	1,260	92
23·7	7,319	115	26·7	4,070	102	29·7	1,168	92
23·8	7,204	114	26·8	3,968	102	29·8	1,076	91
23·9	7,090	114	26·9	3,866	101	29·9	985	91
24·0	6,976	113	27·0	3,765	101	30·0	894	91
24·1	6,863	113	27·1	3,664	100	30·1	803	90
24·2	6,750	113	27·2	3,564	100	30·2	713	90
24·3	6,637	112	27·3	3,464	100	30·3	623	90
24·4	6,525	112	27·4	3,364	99	30·4	533	90
24·5	6,413	111	27·5	3,265	99	30·5	443	89
24·6	6,302	110	27·6	3,166	98	30·6	354	89
24·7	6,192	110	27·7	3,068	98	30·7	265	89
24·8	6,082	110	27·8	2,970	98	30·8	176	88
24·9	5,972	109	27·9	2,872	98	30·9	88	88

* In practice this temperature is best got by swinging a thermometer rapidly round at the end of a string 2 or 3 feet long till it reaches a steady temperature. The thermometer used has a glass ring at one end to allow of its being attached to a string and is known as a *thermomètre à fronde* or 'sling' thermometer, and the temperature so obtained, after a few swings of the instrument, is very nearly accurate.

The following example (taken, with the table, from Mr. Pogson's *Meteorological Reduction Tables*) will explain the method of procedure. The barometer indications having been reduced to 32°, the difference between the corresponding heights, as found in the table, is corrected for temperature; the correction factor being the sum of the shade temperatures at the two places and 900, divided by 1,000, which is multiplied into the tabular difference between the heights. Thus, at Yercaud on the 27th March 1869, Captain Edgcome, R.E., took three observations, at 9-30 A.M., 12-30 P.M., and 4-30 P.M. The reduced readings and corresponding temperatures in shade were—

25·42	25·41	25·33
74°·00	76°·50	77°·00

The means were 25·387 and 75°·8. By applying suitable corrections to the observations made at Salem on the same day the reduced mean barometer reading for the same hours was found to be 28·987 and the corresponding temperature 97°·1 F. We have therefore for comparison—

	Barometer.	Thermometer.
Yercaud	25·387	75°·8
Salem	28·987	97°·1

The corresponding heights as found from the Table are 5,444 and 1,830 feet* giving a difference of 3,614. The sum of the temperatures, *plus* 900, is 1072·9; giving, when divided by 1,000, a correction 1·0729. This multiplied by 3,614 is 3,877 feet, the height of Yercaud above Salem.

Atmospheric Pressure Changes in India.—In the same way as the mean daily temperature is obtained from the readings of thermometers with a certain correction applied, the Mean Daily Pressure of the Atmosphere is deduced from the recorded barometric readings at 8 A.M., 10 A.M., and 4 P.M., and the application of certain corrections.

* In the Table 25·3 corresponds to 5,538, from which is subtracted 0·87 of 108, the number found in the "difference" column. 87 × 1·08 = 93·96; which, taken from 5,538 leaves 5,444·14. So 28·9 gives 1,912 — 0·94 × 87 = 1,912 — 81·78 = 1,830·22.

This method is not applicable except at stations where the average value of the readings has been already ascertained for several years : in other cases the true mean daily pressure can only be found by dividing the sum of the hourly readings by 24. The Mean Monthly or Half-Monthly Pressure and the Mean Annual Pressure are obtained in the same way as the corresponding temperature means.* As the interest of barometric observations, except at great altitudes, is chiefly confined to weather forecasts and the physics of the atmosphere it is not necessary to discuss their significance in detail here. One marked peculiarity in this country is the *smallness of the variations* in the readings except under very exceptional conditions. The Diurnal fluctuation is remarkably regular and is as follows : From 4 A.M. till 9-30 A.M. the pressure rises to its maximum ; falls till about 4-30 P.M.; rises again till 10 P.M.; and, finally, falls till 3 or 4 A.M. The whole change only amounts to about 0·1 inch, and bears no relation to the prevailing weather. Its importance arises from the fact that the changes or undulations due to alteration in the weather are in themselves of very small amount in India and mistakes will arise unless the diurnal fluctuation is discounted. The Annual fluctuations of the pressure in different parts of India only amount to about 0·1 inch to 0·6 inch, proceeding upward from Ceylon to the Punjab.†

From what has been said above, and previously, it follows that until the 'average value' of any place has been fairly well ascertained, a single reading of the barometer will not give any trustworthy information regarding the weather. In other words, the elevation at which the cistern of the barometer hangs must be known to within a foot or two, the daily and seasonal fluctuations allowed for, as also the daily change in temperature, which may amount to between 30° and 40° F. and affects the barometer reading to a corresponding degree. In addition, of course, the

* *v.* p. 301.

† *v.* Table of average monthly readings at various stations. Blandford, *op. cit*, Appendix I.

necessary index and capillarity or other corrections peculiar to the instrument must also be applied. Supposing that all such data are available and have been made use of, a fall of *e.g.*, 0·3 inch below the average of the time and place is strongly indicative of very disturbed weather and it is only in violent cyclones and in the vicinity of the storm's centre that this amount is very greatly exceeded. In the centre of such a storm the pressure may rapidly fall 2 inches below the average of the place and time of year.*

Of much greater value than the information afforded by a single reading at one time and place, is that now made available by means of telegraphic weather-reports from various parts of India. By this latter means a very correct idea of the existing pressure conditions over the Indian Empire at any time can be obtained. "Primarily," says Blandford, "it is some difference in the pressures of different parts of the country and the surrounding seas that determines the course of the winds, and it is the character of the winds as damp or dry that determines that of the weather. The place where the pressure is least, or in other words, where the barometer stands lowest, is usually termed a *barometric depression* or *minimum*,† and the immediate neighbourhood of this depression is the place where rain is most likely, and where it falls most abundantly. The last statement is, indeed, not to be taken without some qualification, but the exceptions are readily recognisable: as a general rule, the maxim holds good."

CIRCULATION OF THE ATMOSPHERE—WIND.

It would be beyond the scope and object of this work to discuss in any detail the causes and nature of the various movements of the atmosphere classified under the generic name of wind. Only the merest outline of the subject can be given here: for fuller information, the student must consult special works.‡

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* Blandford. † *v.* p. 354, and p. 363.

‡ Mill, *op. cit.*; *Elementary Meteorology*, R. H. Scott; Blandford *opera cit*; *Popular Treatise on the Winds*, W. Ferrel; *etc., etc.*

As before mentioned, variations in the atmospheric pressure depend primarily on temperature changes and, to a lesser degree, on the amount of water vapour present at any given time, whilst the pressure variations themselves are the immediate cause of the movements of the air known as winds. Winds have been classified as (1) Permanent Winds, (2) Periodical Winds, and (3) the Variable Winds of high latitudes. It is those of the second class, the so-called periodical winds, which chiefly concern us here.

The general circulation of the atmosphere is brought about as follows: In the intertropical region, extending from about lat. 20° N. to lat. 20° S., and especially over the region of the equator, the air is constantly being strongly heated by solar radiation* and, as a consequence, the pressure is diminished and the heated air rises.† At the polar regions, on the other hand, the air receives but little heat from solar radiation whilst a large amount of heat is radiated into space during the long dark winter period. Here, consequently, the air becomes chilled and

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* *v.* p. 286.

† "If we imagine a column of air confined in a chimney, *extending above the limit of the atmosphere*, and, therefore, only able to expand in a vertical direction, and if we apply heat from below, the total weight will be unchanged, as no air can escape from the chimney laterally; while at any section taken above the base, a greater amount of air will be above that level when the column is heated than when it is at its ordinary temperature, and the pressure at such upper section will be increased. We can prove that this action really goes on in the atmosphere by the following comparison of the monthly mean readings at different levels in winter and summer:

Place.	Elevation, Feet.	Pressure. January, Inches.	July, Inches.	Difference, Inches.
Geneva	1,335	28·66	28·66	0·00
Great St. Bernard ...	8,174	22·11	22·39	0·28
Col. St. Théodule ...	10,899	19·77	20·16	0·39

This shows that while at the lowest of these stations the pressure was the same in January as in July, the increase from the former to the latter month was augmented with the altitude of the station, and at the level of 11,000 feet was as much as 0·39 inches, nearly $\frac{1}{50}$ of its total amount." Thus, "the atmosphere will stand highest over the equatorial regions, as the district where the air is most expanded by the action of heat, *etc.*, and accordingly the pressure in the upper levels in low latitudes will be greater than at an equal elevation above the earth's surface in high latitudes." Scott, *op. cit.*

denser, and descends towards the surface. As a result of the heating and expansion of the air at low latitudes, near the equator, the pressure at the upper level of the atmosphere is relatively high and, conversely, at high latitudes the pressure of the upper levels is relatively low. Now, the atmospheric pressure is constantly *tending* to attain an equilibrium. Consequently, the heated upper strata of air from the equatorial region are set in motion towards the poles, blowing spirally as a W.S.W. wind in the northern hemisphere and as a W.N.W. wind in the southern hemisphere, whilst the cooler and denser air from the polar regions tends to be driven towards the equator as a N.E. wind in the northern hemisphere, and a S.E. wind in the southern hemisphere.

The above may be called the theoretical circulation of the atmosphere. From observation it has been ascertained that the upper currents descend to the surface of the earth at about lat. 20°—30° N. and S., the result being an increased pressure and the production of a region of calm* at these latitudes in both hemispheres—the calms of Cancer and Capricorn. From the regions of these calms, the Trade-Winds, as they are called on account of their steadiness of direction, blow towards the equator. Their primary courses are southward in the northern hemisphere and northward in the southern; but as they reach in succession parts of the earth's surface which rotate eastwardly with greater velocity than that with which they, moving eastward at the rate of circumpolar rotation only, are travelling, they are, as it were, left behind by the intertropical surface, with the apparent effect of making them north-easterly in the northern and south-easterly in the southern hemisphere. Near the equator is the zone of calm, of varying degrees of width according to the season, termed in former days the *Doldrums*, and much dreaded by sailors on account of the absence of wind and resulting loss of time and probable ill-health of the crew.

* With exceptions where the conditions are disturbed by local heating of the earth's surface.

Thus there is a central or equatorial region of calm towards which the N.E. and S.E. trade winds blow, whilst beyond these latter come the tropical belts of high pressure, the calms of Cancer and Capricorn, as before explained. "The tropical regions swept by the equator-seeking (trade) winds are windy, hot, cloudless, but the scene of great evaporation from the hot sea surface. The narrow equatorial belt of low pressure into which the equator-seeking winds blow from north and south is also a region of calm. The air as it ascends here expands, cools, and the enormous supply of vapour swept in from the tropics, condenses into the heaviest cloud, and falls as deluges of never-ceasing rain. The heat liberated by the condensation of so much vapour strengthens the equatorial up-draught. The equatorial belt of low pressure always lies nearly under the vertical sun, consequently in the northern summer it swings to the north, and in the southern summer it swings to the south, displacing the belts of tropical high pressure northward and southward alternately. For reasons which cannot be explained here, this displacement is comparatively slight, extending over only five or six degrees of latitude. All parts of the earth's surface that the equatorial rain-belt traverses in its annual movement experience a rainy season as it lies over them, and a dry season all the rest of the year, when swept by the equator-seeking winds. Near the equator, where the narrow rain-belt crosses a tract of the earth both in its northward and in its southward swing, there are two wet and two dry seasons in the year. The theoretical circulation of the air and its resulting climates are affected by two causes, unequal heating of the air by land and sea surfaces, and the deflection of the prevailing winds by plateau edges and mountain ranges. Consequently, regular zones of surface winds and climates are found only in great expanses of ocean, and do not appear in narrow seas or on land."*

Cyclones have already been alluded to in connection

* Mill, *op. cit.*

with the subject of atmospheric pressure. The term was formerly used to denote a particular kind of storm of great violence occurring chiefly within the tropics. At the present time, however, it is applied to denote the system of winds round a barometric depression—a *cyclonic system*—the reverse condition, the system of winds round a barometric maximum, being termed an *anticyclonic system*. The term, which literally means a circle, is rather misleading for it is now known that the wind blows in *converging spirals* towards the region of low pressure, its strength depending on the steepness or the reverse of the pressure gradient.* In the northern hemisphere the direction of the spirals is opposite to that of the hands of a watch, in the southern hemisphere the direction is the same. In spite of the fact that the air is rushing towards the centre of the cyclone, the latter remains the point of lowest pressure, and thus it is evident that the air must rise in the centre and flow out above, so that above the cyclone, there is an anticyclone of high pressure with outward flowing winds. In an anticyclonic system the conditions of things is exactly reversed, both as to the direction of the wind and the relations of pressure. From the upper regions of the atmosphere air moves in and sinks downward to supply the place of that passing out as surface winds, so that the pressure above the barometric maximum of the anticyclone is relatively lower than the pressure in the neighbouring upper regions of the atmosphere. In an anticyclone the winds are usually light and variable and the weather frequently pleasant.

Of other winds, the so-called south-west and north-east monsoons, land and sea breezes, etc., the consideration must be left till the section on wind observations in India.

Effect of Wind upon Health.—The influence upon health exercised by winds is a dual one and is divisible into (1) Its general influence upon a community; and (2) Its influence upon individual human beings.

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* v. p. 354.

Under the former heading comes the General Action of the wind whereby the air in a town or other place is prevented from stagnating, the polluted air being replaced by pure air. In other words, the 'external ventilation' of any place is chiefly carried on by this means, aided, of course, by circulation, etc., as before described.* With regard to the relationship between wind and the increase or decrease of certain diseases, there is little doubt that under varying circumstances the latter may be diffused by this agency or, in some cases, may be dissipated. Many diseases, such as malaria, cholera, small-pox, plague, influenza, etc., are stated to have been so spread, but the tendency of modern investigation is to show that the statements are wanting in accuracy and that the intercourse of human beings, impure water, food and clothing, etc., are the real channels of infection.† There are strong reasons, however, for believing that in regard to two diseases, *viz.*, malaria and influenza, the movements of the air may play an important part in their diffusion.‡ On the other hand, there is no doubt that many diseases, *e.g.*, typhus fever and small-pox, are favoured in their spread by a stagnant condition of the air, whilst the epidemic may be held completely in check by free ventilation aided by the action of a strong wind bringing abundance of pure air to the infected spot.§

The effects of exposure to the wind in any Individual Case depend chiefly upon its velocity, temperature, and

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* *v.* pp. 18-9. † *v.* Part III. Ætiology of Disease.

‡ The action of wind in directly spreading malaria is certainly very much smaller and less frequent than formerly supposed. It is only where people live near very malarious jungles or swamps, over which the wind blows frequently towards their habitations, that there are any solid grounds for believing in this method of infection. The old idea that the malarial poison could be carried for hundreds of miles by wind is certainly a mistake. In any case it is extremely difficlut to eliminate all the other possible means of communication of the disease.

§ "So convinced were the ancient Greeks of the beneficial influence of wind to combat disease, that at Girgenti (Agrigentum), in Sicily, the traveller is shown the artificial opening which Empedocles made in the rock to admit the Tramontana, or north wind, and thus to dispel the malaria arising from the plain below the city." S. & M., *op. cit.*, pp. 196–7. Curiously enough there is said to be a distinct increase in the number of cases of malarial fever in Sicily and S. Italy during the prevalence of the

humidity. As a rule, the most important effect produced by its action upon the body is cooling. In a cold or temperate climate where people of necessity wear thick and abundant clothing there is little risk of any dangerous degree of *sudden* cooling of the body surface, *i.e.*, 'chill': if from poverty or other reason the body is insufficiently protected in such a climate, the person so exposed will probably suffer from some acute inflammatory condition, such as pleurisy, bronchitis, rheumatic fever, etc. In India the same thing may happen, especially during rainy weather, to those who are lightly clad or who sleep in a direct draught of cold damp wind. But the real and ever present danger throughout the tropics is that of sudden and violent chilling owing to the constant free action of the skin combined with the evaporation set up by the wind, whereby intense congestion of the abdominal viscera is rapidly brought about. This matter has already been alluded to* and it is difficult to exaggerate its importance. At all times of the year it is necessary to be on one's guard against the risk of chill, and most of all after exercise or at night time during the season when a cold, moist wind may begin to blow after some hours of still, sultry weather.†

It is questionable whether the custom of taking exercise before sunrise, on the plains of India, is a good one. Prior to the increase in temperature, which occurs very soon after the sun has risen, the air is usually very stagnant and without doubt is frequently laden with malarious or mephitic exhalations. Formerly this custom prevailed to

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African desert wind or sirocco. This wind, however, is a warm and moist one when it arrives on the N. shore of the Mediterranean and it is probable that the rise in temperature and increased humidity resulting from its prevalence are the essential factors in increasing the amount of malaria. *v.* Hirsch, *op. cit.*, Vol. I., and references given therein.

* *v.* pp. 310 and 327.

† Young and healthy new-comers to the tropics are very apt to make light of this subject, whilst even their elders, who should know better sometimes laugh at the 'fuss' made about chill. It is the duty of all medical officers to explain carefully to the rash and thoughtless how great and real the danger is, yet how easily it can be averted by a little care and a few simple and by no means irksome precautions. *v. post.* Part II., Clothing.

a much larger extent than at the present time and numerous sudden and seemingly inexplicable cases of cholera, dysentery, fever, etc., occurred. Any old Anglo-Indian resident can recall many such instances, which are now, apparently, much rarer than in former years. Amongst natives it is still the general custom to rise very early and go outside to answer the calls of nature, clean the teeth, etc., and there is little doubt that many cases of diarrhœa, hepatic congestion, etc., result from their practice of going out before sunrise, clad in the scantiest of clothing, and exposing themselves to the risk of chill and the respiration of air laden with impurities. As soon as the sun rises the air is set in movement, both in a horizontal and upward direction, and then is the time for exercise, ablution, etc.

In certain parts of India, notably in Sindh and Cutch, a very fatal form of hot wind—the *simoom*—is apt to arise in the hot weather. During its continuance men and other animals are killed, apparently with great suddenness. Its origin and the manner in which it causes death are still quite uncertain, but it must not be confounded with the dust storms which are so common in Northern India. Careful investigation of the exact nature and effects of this phenomenon, more especially with regard to the statements as to its occurrence, etc., made by camel drivers and others, is much required.

The Estimation of Wind.—There are three main points to be noted in wind observations, *viz.*, (1) its *Direction*; (2) its *Velocity*; and (3) its *Pressure*.

To observe the Direction an instrument termed a *wind-vane* is used, which is simply a balanced lever, with one end broad, the other narrow. The latter points towards the direction from which the wind blows, *e.g.*, in a S.-W. wind it points towards the south-west. On the vane rod immediately below the vane is a fixed cross-bar, the extremities of which indicate the four cardinal points. The direction of the wind is judged by comparing the vane pointer with

these fixed points. Great care is necessary in erecting a wind vane, otherwise its indications will certainly be rendered useless by the action of purely local currents of air. It should be fixed on the highest accessible point of a building or other structure, in as open a space as possible, and the cardinal points set by compass.* The indicator should be examined occasionally to see that its movements are perfectly free. Sixteen of the thirty-two points of the compass will be enough to note and register. They are registered by numbers, N. being 0 or 32 and S. 16, the odd ones being omitted. In ordinary Meteorological Stations observations are made at 8 A.M., 10 A.M. and 4 P.M.

The Mean Direction is generally calculated by adding together the number representing the points noted and dividing by the number of observations. If no two points observed differ by more than 16—in other words, if all the points, projected on a circle, are in the same semi-circle—this method may be used. Otherwise, the points observed should be represented on the circumference of a circle by marks in positions corresponding to the observations; when the eye can determine which part of the circle would gravitate lowest if the marks were weights, and this part indicates the mean direction. As, however, the varying velocity of the wind is not taken into consideration in the observations the determination of the mean direction is of little practical utility. In addition, the direction, as indicated by the wind vane, is much influenced by local conditions, *e.g.*, presence or absence of trees, the contour of the ground, etc.

To estimate the Velocity of a wind various forms of *anemometer* are used, the best known of these being Robinson's anemometer. It consists of a revolving vane with four crossed arms carrying four hemispherical cups of

* To the true, not magnetic, north. The declination of the compass is very small in any part of India, not exceeding 2°, and magnetic north is east of true north. This variation, small as it is, must not be disregarded, otherwise there will be a serious error in the average of a large number of observations. Blandford.

thin sheet copper. In the larger instruments the vane revolves with one-third of the velocity of the wind, but in every case the instrument, whether small or large, requires correction for friction, etc., and must be carefully compared with a standard anemometer. The revolving vane communicates its movement to a train of toothed wheels which, in turn, indicate the distance travelled on a dial. They usually register up to 1,000 miles. To read the anemometer it is necessary to subtract the previous reading from the total, and then, if the difference so obtained is divided by the number of hours or minutes since the last reading, the result will be the average rate per hour. To this reading the necessary correction must, of course, be applied. The small *air-meter* of Casella has already been referred to*; its principle is much the same, only it is a more delicate instrument and is used for recording the rate of movement through ventilatory openings, etc.

If there is no anemometer, a useful record of the approximate wind velocity may be kept for any place by the use of the so-called Beaufort scale, as here given, in much the same way as the amount of cloud is noted.

		Approximate velocity. Miles per hour.
Calm	0 ...	0 to 5
Light Wind ...	1 ...	6 „ 15
Moderate	2 ...	16 „ 25
Fresh	3 ...	26 „ 36
Strong	4 ...	37 „ 52
Heavy	5 ...	53 „ 80
Violent (hurricane)	6 ...	80 and upward.

For recording the Pressure exercised by wind, numerous *pressure gauges* have been invented. One of the oldest and simplest, and one which has been lately recommended for general adoption, is essentially the same in appearance as a swinging sign-board, *viz.*, a plate or sheet of metal suspended vertically on bearings from a horizontal fixed

* *v.* p. 42.

bar, so that when the wind blows against its surface it swings backward; the angle which it thus makes indicating the amount of pressure, as originally determined by experiment. It is attached to a large vane which keeps it always facing the wind. Another form is that known as Osler's wind gauge, the essential part of which is also a metal plate behind which there are springs whose elasticity serves to measure the force of the wind. None of the instruments yet invented is free from error and it is further found that instruments varying in size or construction do not agree in their records. Another very important point is this, that during gales of wind when the estimation of the pressure is of the greatest importance, there are *sudden and great variations* in the pressure exerted both as regards its amount and direction. For example, a structure which is evidently stronger than a neighbouring one may be blown down, whilst the weaker one is left uninjured.

Besides the direction, velocity and pressure of the wind, the observer should note the times at which it begins and subsides, or suddenly changes its course; the direction of the changes; the point from which it blows steadily after alterations or fluctuations; the existence of currents in the upper regions of the atmosphere (shown by cloud-movements)*; the times when hot or cold winds set in and the points from which they blow; the connexion of weather—cloudy, rainy or fine—with the quarter from which the wind is blowing, or has been blowing for some time previously.

In daily weather reports the points usually given with regard to the wind are (1) The Mean Direction and (2) The Velocity in 24 hours. The actual discussion of wind observations is a complicated matter and cannot be further alluded to here. It should be noted that anemometers merely record the horizontal motion of the air and take no account of the important upward and downward motions due to convection, etc. Probably the most satisfactory method of recording the wind observations of any station

* *v.* p. 323.

is by a *wind-rose* which consists of a table or diagram constructed to shew the percentage proportion of the number of wind observations from sixteen points of the compass and sometimes also, the varying force of the wind. In other cases a table is given showing the Mean Monthly Resultant Wind Direction and Velocity. The *wind-resultant* is compounded of direction and velocity and gives the position which a body, freely moving under the influence of wind alone, would occupy after a given time. It is obviously most important for sanitary purposes; being capable, for instance of determining whether malaria or other material poison has been borne by the wind from one place to another. It requires, however, frequent observations and complicated calculations and is, unfortunately, rarely attainable.

Observations on the Wind in India.—The chief characteristic of the winds in this country is their prevailing lightness, though at times, of course, they may blow with tremendous violence during a cyclone or other storm. Owing, also, to the very various climatic conditions which are found between the limits of the Empire, almost every kind of wind may be encountered, such as very hot or very cold winds, very dry or very damp winds, special winds giving rise to dust storms, the peculiar wind known as the simoom, etc., etc., and not only so, but in certain localities when the annual ranges of temperature and humidity are very great, almost every variety of wind may be experienced in the course of twelve months. In a country like England, people naturally lay great stress on the direction from which a wind is blowing, *e.g.*, the east wind is practically always a cold wind, the south wind a warm wind, and so on, but in this country much more stress is laid upon the fact as to whether a wind is a land wind or a sea breeze, a wet wind or a dry wind, and the reason is obvious enough, for a wind in traversing the peninsula may keep the same direction approximately but completely change its character, whilst a sea breeze is always a cool wind whatever direction it blows from.

As with temperature, pressure, and humidity, so with the wind, there is a regular Diurnal Variation in its velocity, which at certain seasons is completely masked or obscured, but occurs at other seasons for days together. It follows very closely the daily temperature fluctuation, so that the air is stillest just before sunrise, after which a light breeze springs up and continues to increase till about 2 P.M., again declining towards evening *pari passu* with the temperature.

At places situated near the sea, this daily wind is most frequently a sea breeze, but not always so; it may simply be that the prevalent wind at that particular season increases in force as above described, but its direction, though slightly modified temporarily, may be seawards or, in fact, from any point of the compass. Sometimes a land wind at night alternates with the sea breeze during the day, the changes in direction occurring after well-marked morning and evening periods of calm. This is commonly the case during the intervals between the strong winds of the summer and winter monsoons, the alteration in direction being brought about, roughly speaking, by the relatively more rapid absorption and radiation of heat by the land surface as compared with the water.*

Two winds, common to mountainous countries, are met with in the Himálaya and other parts of India, and as they bear an important relation to health, they deserve mention. These are respectively the 'down-valley' and 'up-valley' winds. The former blows with great force where the valleys widen out into the plains and begins suddenly in the early morning after the period of calm. In the same way the up-valley wind blows strongly upwards, especially in the narrow mountain passes, during the afternoon hours, subsiding at sunset. As these winds blow with great regularity at certain seasons, the traveller, whether camping or marching, should be on his guard against receiving a chill when sleeping or when lightly clad.

* For explanations and diagrams illustrating this and other wind phenomena, *v. Met. Vade Mecum*, Part II., and Mill, *op. cit.*, p. 128, etc.

The Annual Variation in the direction of the winds in India is so marked a feature that the two *monsoons* are popularly known as the South-West monsoon and the North-East monsoon. But, as pointed out by Blandford and others, these names are inaccurate and misleading for many places, so that the terms Winter and Summer monsoons are to be preferred. Into the cause of these great changes in the atmospheric circulation, so far as known, it is impossible to go here and only the merest outline of the subject can be given. If a series of charts showing the average monthly distribution of atmospheric pressure over the Indian peninsula and neighbouring seas be examined, it will be found that in the month of January (*v.* pl. xx.) the pressure is lowest at two principal regions, *viz.*, to the south of Ceylon and near Sumatra, whilst it gradually increases northwards till it reaches its maximum in the extreme north-west of India. In the month of July (*v.* pl. xx.), on the other hand, this condition of things is exactly reversed, so that the barometric minimum is found in the region of Upper Sindh, and the maximum near Ceylon and Sumatra. In general terms, this shifting of the pressure which goes on from January to July and July to January, is brought about by changes in temperature, the seat of highest pressure being the place where the temperature is relatively lowest and *vice versâ.*

During March and April the weather over the Arabian Sea is generally fine; in the Bay of Bengal it is uncertain, and dangerous cyclones sometimes form. In May, south-west winds begin to blow in the Bay of Bengal, and later, west to south-west-winds blow from the Arabian Sea on to the west coast of India. The former sweep over the S. of India and Ceylon up the Bay and become divided into two main currents of which the larger part passes over Burmah and Assam to the eastern Himálaya, whilst the remainder curves first to the south in Bengal and then recurves along the face of the Himálaya, becoming an easterly wind up the Gangetic plain. The latter, *i.e.*, the westerly and

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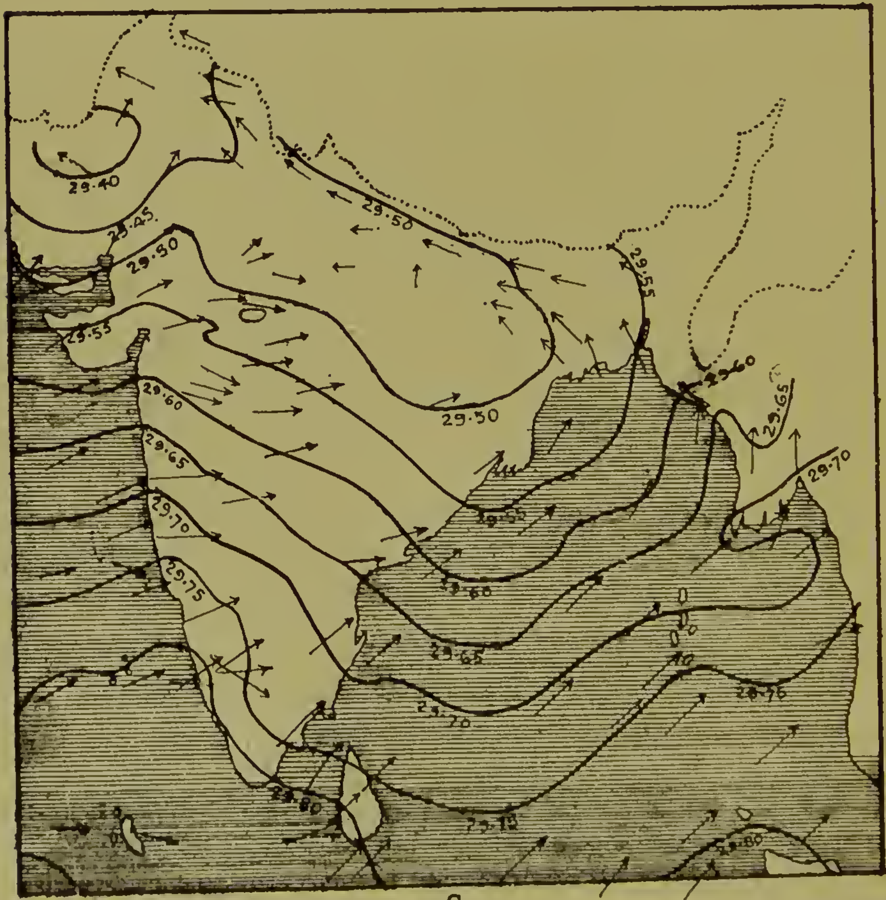

2.

LITH. BY ROSS, BROS.

To face p. 372.

PLATE XX.

BAROMETRIC AND WIND CHARTS—INDIA. (AFTER BLANDFORD).

To illustrate the various points alluded to on p. 354, and to show the Annual Variations in the Wind Direction due to the Gradual Shifting of the Centres of Highest and Lowest Barometric Pressure respectively.

Figure 1. Average for the month of January.

Figure 2. Average for the month of July.

south-westerly winds from the Arabian Sea, blow right across the peninsula as far north as the Satpura range in Central India. Both currents bring with them deluges of rain which fall chiefly on the west coast of India, the west coast of Burmah, and the eastern Himálaya and Assam.* In the North-West of India the winds are at this time variable and uncertain, as is also the case in the region of country between the westerly current reaching as high as the Satpura hills and the easterly current sweeping up the Gangetic plain. During the summer monsoon the lower half of the east coast of India, the Carnatic, receives but a small portion of its annual rainfall, for the south-westerly current up the Bay of Bengal passes it by almost entirely, whilst the wind which reaches it overland has parted with most, if not all, of its excess of moisture on the other side of the peninsula.

In October and November, however, as the centre of low pressure is gradually moving south, it lies over the Bay, opposite the coast of Madras, and it is then that the north-easterly wind begins to blow strongly and ushers in the winter monsoon. During the months of October, November, and December Madras receives about 30 inches of its annual rainfall of 49·02 inches. In the southerly portion of the Bay the north-east wind continues to blow till the end of February and then, becoming more unsteady, gradually veers to the east and sou' sou'-east—the 'long shore wind' of April and May—till its place is taken by the advancing south-westerly current of the summer monsoon. In other parts of India, during the so-called 'cold weather,' the winds are very light and in many places there is calm for days together.

It is thus evident that the terms south-west and north-east are inaccurate for a large part of India. In addition, it must be carefully noted that the winds of the monsoons are not nearly so constant in their force and direction as is commonly assumed, and finally, that the summer mon-

* *v. ante*, Rainfall, p. 329, *et. seq.*

soon is essentially *the* monsoon, whilst the winter monsoon affects only a very small portion of the Indian peninsula in any marked degree.

The following table is instructive as showing clearly the gradual change in direction and velocity of the wind throughout the year.*

MEAN MONTHLY RESULTANT WIND DIRECTION AND VELOCITY.
MADRAS—MEANS OF 23 YEARS.

Months.	Miles.	Points.
January ...	130	N. E.
February ...	95	East.
March ...	135	S. E.
April ...	169	S. E. by S.
May ...	164	S. by E.
June ...	133	S. W. by S.
July ...	131	S. W.
August ...	101	S. W. by S.
September ...	84	S. W. by S.
October ...	44	N. N. E.
November ...	120	N. N. E.
December ...	154	N. N. E.

LIGHT.

Though a climatic factor of great and undoubted importance, Light does not usually receive special notice in meteorological observations and records save in the form of sunshine or direct sunlight. It can only be briefly considered here in its immediate relation to health generally and to health in India in particular.

Light in relation to health.—Reference has before been made to the important influence exercised by sunlight, both diffused and direct, upon living organisms.† A most

* Compiled from table given on p. 394 of *Results of the Meteor. Observations at the Government Observatory, Madras, from 1869—1890*, edited by C. Michie Smith, B.Sc. F. R. S. E., an invaluable work for all interested in the Meteorology of India.
† *v.* p. 292.

notable point and one pregnant with suggestion to the hygienist is the fact that whilst to the higher classes of organisms, such as human beings, flowering plants, etc., abundance of light is essential to health, the lower organisms, such as many of the invertebrate animals, cryptogamic plants, etc., can carry on a healthy existence in the entire absence of direct sunlight, and, finally, the lowest classes, including specially, various forms of animal and vegetable parasites, are able to dispense altogether with light during their brief cycle of existence.* The above is not to be taken as invariably true, for there are many marked exceptions; but it is found that where an organism or class of organisms originally living in strong light, is compelled, through change of environment, to exist for successive generations in almost complete darkness, it undergoes marked structural alterations of a degenerative nature. Many animals, of course, are more or less nocturnal in their habits and others pass a great deal of their time underground, but in most of these cases the deprivation of light is not so extreme as the superficial observer might imagine.

The most marked effect of absence or deficiency of light upon human beings and plants is 'etiolation.' If some rice, sown on a moistened flannel cloth, or upon earth, is kept in a dark place, it will be found that it will germinate but that the stalks and leaves will be of a pale yellow colour instead of green, and that it will not ripen. The same experiment is often performed in nature and may be demonstrated by turning over a heavy stone under which grass is growing. The portions of the grass which have been freely exposed to the light will be quite green, whilst those to which light has not had access will be pale and etiolated. "Without light there is no fructification, and, indeed, few plants can flower without direct sunshine. Under the influence of light plants absorb carbonic acid from the air, the carbon is fixed, and the oxygen is exhaled, a process of nutrition which ceases in the dark.

* v. Part III.

According to Carpenter, Henfrey, Ellis, Garreau, and others, plants also respire continuously night and day, producing small quantities of carbonic acid, formed by the combination of oxygen with their superfluous carbon, a process of combustion which continues in the dark. Thus we see why in high latitudes, where the days are long and even extend into months when the sun never sets, there is almost a quite uninterrupted progress and that is why growth in those countries is so rapid, and why plants will fructify more rapidly there than in the hotter but shorter days of the south."* Sunlight, then, is of extreme importance to mankind both as furnishing the plants whereon we subsist with the power of assimilation and as maintaining the purity of the atmosphere.†

Amongst the human race the evil effects of living and working in deficient light are sometimes obvious enough, but as a rule, in such cases, there are many other contributing factors to ill-health, and it is extremely difficult to assign to each its proper share. Especially should it be noted that pure air and abundance of light are almost always found together and the marvellous effects produced upon children removed to the country from the foul air and narrow streets of large cities, though partly attributable to improved diet, are undoubtedly due in a measure to the beneficent action of light and sunshine.

Many people are extremely sensitive to alterations in the amount of sunlight, especially those who go from the sunny climates of S. Europe and the East to dwell in Great Britain. The lowered temperature and the frequent rain do not depress them nearly so much as the long, gloomy winter months and the constant fogs‡ in the great cities.

On the other hand, too frequent exposure to intense sunlight may produce serious injury, especially upon the extremely sensitive retinal membrane of the eye. Most of the ill effects due to exposure to the sun have already been

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* G. T. Symons, F.R.S., quoted by Dr. Sykes, *Public Health Problems*, p. 30.
† *v.* p. 284 and *f. note*. ‡ *v.* p. 319.

stated to be due to excessive heating of the body, but in the case of the eye, the injury is caused by the constant stimulation of the retina by the light rays, whereby the stock of retinal pigment is exhausted more quickly than it can be renewed, and this is specially the case in men fatigued or weakened in any manner by disease. Sometimes, as a result of this overstimulation* by day, the condition known as 'night-blindness' is set up. When this occurs, the eyes must be carefully protected during the day time by neutral-tinted spectacles or other means, and, if nothing better is available, the right and left eyes should be covered with a bandage during the daytime on alternate days.

Light in relation to health in India.—There are one or two points calling for special notice under this heading. To a new-comer from northern latitudes one of the most striking things on arrival is the intensity and constancy of the sunlight, and conversely, on first entering an Indian house, more especially if it is one belonging to a native of this country, he wonders at the sudden change from the brilliant sunshine outside to the comparative obscurity within. Where coolness is made entirely dependent upon the exclusion of direct sunlight, a state of semi-darkness follows of necessity, as also defective ventilation.† From the injurious custom of shutting themselves up for many hours daily in a much darkened house arose a good deal of that pallor ‡ that was formerly so characteristic of Anglo-Indians, and especially of the women and children ; though doubtless the excessive heat contributed, and still contributes, an important share in its production. Of late years things are much improved in this respect owing to the improved habits of Anglo-Indians in the taking of exercise,

* "It has been estimated that the light emitted by the sun and falling on the page of such a book as this is about 60,000 times greater than that of a good wax candle placed at a distance of 1 yard from it, and about as much greater than the light of the moon at the full." H. Power, F.R.C.S. The only artificial light of sufficient intensity to cause serious injury to the eye is the naked arc electric light.

† v. p. 226. ‡ Strictly analogous to the 'etiolation' of plants.

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in not completely shutting up the house, save in the hottest weather, and so on, but the evil can never be fully remedied till the designing, construction, and ventilation of houses in the tropics receive the careful consideration which the importance of the subject merits.

With regard to the mass of the people in India, the only class which appears to suffer much from the evil of deficient light,—in addition to deficient ventilation, bodily exercise and mental recreation,—is that of the wives of high-caste Hindus and of Mahommedans, who spend the greater portion of their lives in the seclusion of the womens' quarters or zenana and who, if they do take 'carriage exercise' (*sic*), do so with the blinds drawn or closed and darkened glass windows. The poorer classes, especially, pass their life to a large extent in the open air and it is probable that the death rate of the children would be even higher than it is were it not that conditions unfavourable to vitality are partially compensated for by free exposure to light.

When there is a possibility of long continued exposure to the 'glare' of sunlight* reflected from a white surface, more especially snow, great precautions should be taken to protect the eyes as before mentioned.† Medical officers and others who may be compelled to drive in open carriages during the day time in the hot weather may save themselves from headache and, possibly, permanent injury to the eyes by wearing neutral-tinted 'goggle' spectacles which exclude excess of light, heat and dust, and give a most delightful sense of coolness to the eyes.

ATMOSPHERIC ELECTRICITY.

Comparatively little is known with regard to atmospheric electricity in India or elsewhere and the whole subject is one that requires far more systematic observation than has yet been attempted. The general conclusion arrived at many years ago by Lord Kelvin and others is

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* *v.* pp. 293–4.

† *v.* p. 377. For an account of 'snow-blindness,' by Dr. H. Cayley, *v.* *I.M.G.*, 1868.

that in fine weather the potential of the air relatively to the earth is positive but that in stormy weather it is often negative. In India this conclusion requires modification in one important respect, for observations made in Madras* have shown that in fine weather with a dry west wind the normal state of affairs is that the potential of the air becomes negative as soon as the surface of the ground gets heated—say between 9 and 10 A.M. This is almost certainly due to the dust in the air.

Observations upon atmospheric electricity are most easily made with one of Sir William Thomson's (Lord Kelvin's) portable electrometers.

The relation between health and atmospheric electricity is probably close and important, but too little is at present known to make a discussion of the subject here of any value.

ATMOSPHERIC DUST.

There are three chief sources of the dust† with which the atmosphere surrounding this earth is laden, *viz.*, (1) Meteorites; (2) Volcanoes; and (3) The general wear and tear of the Earth's Surface due to natural causes and human operations.

Meteors, or 'falling stars' as they are erroneously called, consist of masses of solid matter of varying size, which seem to be scattered in incalculable numbers through

* *v. Atmospheric Electricity*, by C. Michie Smith, B.Sc., Phil. Mag., Nov., 1885, and references therein given to other papers.

† To illustrate how extremely light are these minute dust particles, which are found by experiment to take several days to settle, even in perfectly still air, the following example from Mill, *op. cit.*, p. 109, will suffice. "When a cube of stone 1 inch in the side is falling, its mass drags it down, and the friction of the air on its six square inches of surface, resists the fall. If the cube were cut into ten slices $\frac{1}{10}$ of an inch thick, each of these into ten bars, and each of these into ten cubes $\frac{1}{10}$ of an inch in the side, there would result 1000 little cubes drawn down by the same force as had acted on the one; but the atmosphere would now have sixty square inches of surface to act on. If each of these little cubes were cut into 1000 the downward attraction of the earth on the whole million would be the same as for the one-inch cube, but the air-break would be applied to no less than 600 square inches of surface, so that their fall must be very slow indeed. The average dust-motes of the air are much smaller than these, hence it is not surprising that even the stillest air [in nature] is never free from dust." *v.*, also, *The Floating Matter of the Air*, by Tyndall.

space.* When they enter this earth's atmosphere they do so with an enormous velocity and, the energy of motion being converted by the friction of the air into heat, they are very rapidly heated, the larger ones becoming visible for a few seconds as so-called falling stars. Thereafter they are dissolved into fine dust which, owing to its extreme lightness, is capable of long periods of suspension in the atmosphere.

During volcanic eruptions an immense amount of fine dust and ash are carried up into the atmosphere by the explosive force of the steam emitted. For example, in the great eruption at Krakatoa, a small island in the Eastern Archipelago, on the 27th August, 1883, the column of dust and vapour was estimated to be 20 miles in height, and the dust was carried to all parts of the earth, giving rise to beautifully-coloured sunsets and various other phenomena.

Allusion has already been made† to the third source of atmospheric dust, to which the various occupations and industries of the human race contribute no inconsiderable amount. Amongst the immediate sources of dust under this heading come first the constant wearing down of the earth's surface by the action of rain, frost, wind, and other agents of denudation, and the solid particles of sodium chloride and other salts derived from sea spray; secondly, the enormous number of minute animal and vegetable organisms, dead and living, which are constantly passing into the air, as also, the pollen from forest trees and smaller plants; and thirdly, the very varied dust given off from the combustion of coal, wood, and other fuels, from mills and factories of all kinds, and indeed from any place which human beings inhabit. Mr. Aitken, whose researches are referred to later, has found, when examining into the amount of dust in the air of an open space in the country, that it is easily possible to detect the existence of a house or houses invisible to the observer by a change in the direc-

* It has been estimated that about 20,000,000 meteorites reach the earth daily.

† v. p. 6, *et seq.*

tion of the wind, whereby the latter, instead of reaching the observer after blowing over uninhabited country, is caused to blow over a small village or other inhabited place. An immediate rise in the number of dust particles is the result.

Having proved by experiment that moisture always condenses upon a solid nucleus, which is generally a dust particle, Mr. Aitken took advantage of this discovery to invent an apparatus by means of which the number of dust particles in any sample of air might be ascertained. This Dust-Counter cannot be described in detail here, but the principle of its construction and use is as follows :

An *inverted* flask of known capacity is filled with dust-free air obtained by drawing air into it through a cotton wool filter.* Into this flask is admitted a measured amount of the air to be examined, say 2 c.c. Inside the inverted flask at a certain distance from its inverted bottom is a small counter† with a silvered surface. By a simple device the air in the flask is kept almost completely saturated, so that by a sudden reduction of the pressure—by means of a stroke of a small air-pump attached—the moisture is condensed upon the dust particles within the flask. All the minute droplets thus formed in the air between the bottom of the flask and the upper surface of the counter, say 1 c.c., fall upon the latter, whose surface is divided into measured squares. By counting the number of droplets on a certain number of these squares, through the aid of a hand lens, the total number of dust particles contained in the air above the counter, *i.e.*, in 1 c.c., is found, and from that is calculated the total number in the flask, *i.e.*, in the 2 c.c. of dusty air originally admitted. From this result a simple calculation will give the number present in a cubic foot or any other desired amount of the original air. Since the invention of this apparatus Mr. Aitken has designed a more portable one which he has named the Pocket Dust-Counter. Careful observations in India with this instrument, if

* Of the same nature as those used in bacteriological work, *v.* Part III.

† Analogous to those used for counting bacterial colonies, or the corpuscles of the blood.

sufficiently numerous and combined with simultaneous meteorological records, would doubtless yield very interesting results.

The number of dust particles in the air has been found to vary enormously both at different places and at the same locality under varying conditions. Thus, in illustration of the former statement, the number has been found to vary from 0 dust mote in 1 c.c. of air on the top of Ben Nevis, the highest hill in Great Britain, to 210,000 in 1 c.c. in the air of the city of Paris. In illustration of the latter statement, a reference to Mr. Aitken's researches and tables shows that the air in Dumfries, a town in Scotland, contained 11,000 particles per 1 c.c. at 10 A.M. one day, whilst next morning at 10 A.M., there were but 325 per 1 c.c. For these variations there are very numerous reasons, such as the strength and direction of the wind, presence or absence of rain, etc. A summary of the conclusions arrived at by the above observer is herewith given, but the whole subject is still far from being completely elucidated.

1st. The earth's atmosphere is greatly polluted with dust produced by human agency.

2nd. This dust is carried to considerable elevations by the hot air rising over cities, by the hot and moist air arising from sun-heated areas of the earth's surface, and by winds driving the dusty air up the slopes of hills.

3rd. The transparency of the air depends on the number of dust particles in it, and also on its humidity. The less the dust the more transparent is the air, and the dryer the air the more transparent it is. There is no evidence that humidity alone—that is, water in its gaseous condition, and apart from dust—has any effect on the transparency.

4th. The dust particles in the atmosphere may have vapour condensed on them even though the air itself is not saturated.

5th. The amount of vapour condensed on the dust in unsaturated air depends on the 'relative humidity' and also on the 'absolute humidity' of the air. The higher the humidity and the higher the vapour tension, the greater is the amount of moisture held by the dust particles when the air is not saturated.

6th. Haze is generally produced by dust, and if the air be dry, the vapour has but little effect,—and the density of the haze depends chiefly on the number of particles present.

7th. None of the tests made of the Mediterranean sea air show it to be very free from dust.

8th. The amount of dust in the atmosphere of pure country districts varies with the velocity and direction of the wind; fall of wind being generally accompanied by an increase in dust. Winds blowing from populous districts generally bring dusty air.

9th. The observations are still too few to afford satisfactory evidence of the relation between the amount of the dust in the atmosphere and climate.*

It should be noted that these observations have reference solely to the quantity of dust present and take no account of its quality. In its relationship to health both aspects of this question are of importance. For example, instances have been given in the first chapter† where in the one case it is more especially the *quantity* of dust inhaled which is injurious, whilst in another it is the *quality*, though of course the quantity and quality are more

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* Mr. Aitken's papers have already been referred to, *v. f. note** on p. 318. The large Dust-Counter will be found figured and described in Trans. R.S.E., Vol. XXXV., 1888; the Portable Dust-Counter in Proc. R.S.E., Vol. XVI., 1889; and the paper here referred to, in Proc. R.S.E., Vol. XVII., 1889-90.

† *v.* pp. 6-7.

or less correlated.* It is, roughly speaking, the inorganic dust particles which are harmful only when present in great quantity, whilst a very small amount of organic particles if consisting of pathogenic organisms may give rise to serious disease. This may be called the *individual* relation of dust to the health of human beings. The tendency of the researches above referred to is to show that it exercises a most important *general* influence upon health, by the intimate relation that exists between the amount of atmospheric dust and the temperature of. the air, its humidity, transparency, electrical condition, etc., etc. There is no doubt that future investigation in India will demonstrate most important relationships existing between the health of communities according as they live in crowded and dusty cities, less dusty villages, or in the purer air of the hill sanitaria, and that the relationship will prove to be both an individual and a general one.

CLIMATOLOGY.

Having studied individually each of the important factors of climate, it is now necessary to consider them collectively as constituting, by their various local manifestations, the climate of any particular place. At the commencement of this chapter climate was defined as 'the sum of the local atmospheric and physical conditions in their relationship to animal and vegetable life,' and in the study of Climatology it is the aim of the investigator to compare together and classify the different varieties of climate and their effects upon health, as also upon other important economic conditions with which we are not here concerned. In chapter III. it was shown how *direct* is the connection between health or the reverse and the physical conditions obtaining at any place, and it is evident from what has been said previously in the present chapter, that the temperature, rainfall, humidity, and other climatic factors are

* Somewhat in the same way, one sample of water may be injurious to health owing to the quantity of impurity, *e.g.*, magnesium sulphate, whilst another sample may contain a very small quantity of impurity, but what there is may be of very injurious quality, *e.g.*, the poison of typhoid fever.

greatly modified by local physical conditions, which latter thus exert an *indirect* influence upon health as well. It is necessary, therefore, before going further, to say a few words regarding the geographical position and surface characters of this country in so far as they bear upon health, directly or indirectly.

Roughly speaking, the Indian Empire extends at its longest and broadest parts from the eighth to the thirty-sixth degree of north latitude and from the sixty-second to the one hundred and third meridian of east longitude. Disregarding for the present that part of the empire known as Burma, let the student examine carefully the position and form of the great peninsula which constitutes India proper. A little thought will show him that to its geographical position are largely due the varied climatic peculiarities it presents. Firstly, the larger part of it lies within the tropical zone and the remainder lies just beyond, and though the whole of it is situated to the north of the equator it is still one of the hottest places in the world. This is because the line of greatest mean heat—the so-called *thermal equator*—does not follow the course of the true equator but, in the longitude of India, bends northward, running up through Ceylon and the Peninsula to beyond the tropic of Cancer and passes through Sindh to the Arabian peninsula : furthermore, where this line traverses the low plain of S. India is one of its hottest portions.* Again, though the mean annual temperature is highest in Southern India, the highest temperatures of the year occur in the N.W. of India, and especially Sindh, during May and June.

The next point claiming attention is the peculiar relation of India to the rest of the great Asiatic continent, from which latter it projects, as it were, into the sea, so that to the north of it is an enormous extent of land, whilst to the south there is practically nothing but the open sea. Further, right along the north of India and for a consider-

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* Blandford.

able distance along its N.E. and N.W. boundaries runs an immense series of mountains, amongst them the loftiest peaks in the world. From the Himálaya a vast tableland from 11,000 to 18,000 feet above sea level extends northwards for 600 miles and terminates in a desert. To this peculiar geographical position, as before stated, are due many of the curious and pronounced differences that exist in the climates of different parts of India.

Along the western side of the peninsula runs the great chain of mountains, forming the Western Ghâts (*Sahyádri*), which exercises such an important influence on the distribution of the annual rainfall. Across the country from the gulf of Cambay almost to the Bengal plain runs another series of hills, the Sátpura and Arvali* ranges and the highlands of Chutia Nagpore, which latter do not form a continuous mountain system but are in reality a belt of high land representing the remains of vast rock formations that have been worn down and denuded to the north and south. Lastly, along the E. coast there is a broken series of hills, not nearly so well-defined and continuous as is commonly imagined, which is known as the Eastern Ghâts and is probably similar in mode of formation to the Central Indian ridge.

Between the Himálaya mountains and the hills of Central India lie the great river systems of the Brahmaputra, Ganges, Indus and other rivers. South of the Sátpura and neighbouring ranges stretches the tableland of the Deccan, merging gradually into the plains of Southern India, whilst the Western and Eastern Ghâts converge to a point at Cape Comorin.†

Even from the foregoing condensed description of the most noticeable physical features of the country the student would be prepared to expect that the local conditions must vary greatly in different places. Such indeed is the case to a most remarkable degree and it may be

* Striking nearly S.W. to N.E. in Rajputana.

† Strictly speaking, the Eastern and Western Ghâts unite just to the south of the Nilgiri hills, whilst an irregular chain of hills runs down from there to the end of the peninsula at Cape Comorin.

said without fear of exaggeration that there is hardly a physical feature or condition met with in the various parts of the earth's surface that is not to be found somewhere in India. There are hills of every elevation from a few feet above sea level to the greatest height* in the world. There are hills whose peaks rise far above the line of perpetual snow, there are others clad with dense tropical and sub-tropical growths to their summits, whilst others are devoid of any larger plants than small shrubs and coarse grass. There are elevated tablelands from which the snow never melts, there is the jungle-covered tableland of Central India, the bare and rocky tableland of the Deccan, the grassy tableland of the Mysore plateau. There are immense rivers running through rich alluvial valleys, which yearly carry seawards the water from the melting snows, there are rivers which at certain seasons are raging floods at others a mere streak of water in a vast sandy bed, whilst many remain completely dry for months together. There are dry sandy deserts, rich plains well-watered by nature or irrigated by canals, the deadly *terai* jungle at the foot of mountain ranges, lakes, swamps and backwaters, and many other physical features peculiar to different portions of the country.

Classification of Climates.—Climates have been very variously classified by different writers. It might appear at first sight as if a classification by *latitude* was feasible, but a little consideration will soon show this to be impracticable :† so, also, by *isotherms*,‡ since two places with the same mean annual temperature may have very different climates, as already explained.§ No strictly scientific arrangement is possible. Probably the three most important points to be considered in classifying climates are (1) the latitude; (2) the relative quantities of land and water surface; and (3) the altitude above sea level. But there

* Mount Everest, 29,002 feet.

† *v.* p. 286, *para.* 4.

‡ Analogous to *isobars* (p. 354), but indicating places with the same *mean annual temperature.*

§ *v.* p. 301.

are many other important things to be noted, such as the humidity, prevailing winds, ocean currents, etc.

The following classification is that adopted by an eminent authority, Dr. C. Theodore Williams.*

1. *Warm Climates: Equatorial; Tropical; Sub-tropical.*—Climate of regions lying between the equator and 35° latitude N. and S. Characterised by high temperature, with (as a rule) heavy rainfall, and dry and rainy seasons.

2. *Temperate Climates.*—Climates of regions lying between 35° and 50° latitude, with four well-marked seasons—a preponderance of rainfall in autumn and winter—having a mean temperature from 50° F. to 60° F. and considerable extremes.

3. *Cold Climates.*—Climates of regions lying between 50° latitude and the poles, marked by gradual reduction of temperature as the pole is approached, the greatest cold being 10° from it. The season there consists of a long winter of ten months and of a few weeks of summer. Rainfall small and generally in form of snow. Aurora borealis frequent.

4. *Marine Climates.*—Characterised by the presence of the marine influence—*i.e.*, coasts, islands, peninsulas washed by the ocean or salt seas, and owing their freedom from extremes to warm currents and the equalising influence of the ocean. Such is the climate of Great Britain, of Ireland, of Norway, and of many islands. We also include in this division the climate experienced in sea voyages.

5. *Mountain Climates.*—Characterised by diminished barometric pressure, increased diathermancy, and by extremes of temperature.

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* *v.* S. and M., p. 203. It is much the same arrangement as that of Dr. Henry Bennett, *v.* Quain's *Dict. of Med.*, article 'Climate.'

In the above classification it will be seen that the first three divisions are arranged according to latitude; in the fourth, latitude is practically disregarded whilst the influence of a large surface of water, such as the sea, receives the chief place; in the fifth, elevation above sea level is the principle feature.

Another great authority, Dr. Hermann Weber, makes the presence or absence of the 'marine influence' the primary basis of classification and arranges them thus:

A. *Marine Climates* (Island and Coast climates).

1. Humid Marine Climates { Warm / Cool.
2. Marine Climates with Mean Humidity.
3. Dry Marine Climates.

B. *Inland Climates.**

1. Altitude or Mountain Climates.
2. Lowland or Plain Climates.

From the above the student can see how different are the proposed arrangements and how empirical or incomplete the classification adopted, but he will be enabled to form some idea of the leading types of climate and what points receive special attention. Very full information can be obtained from any of the articles alluded to.†

The main object of the study of climatology is to ascertain the nature of the relationship that undoubtedly exists between certain climates or climatic conditions and certain diseases, in the direction of favouring or checking the development of the latter. Thus, the various diseases known under the generic name of phthisis require very different climates for their improvement, according as they are of tubercular or pneumonic origin, and a climate very

* "The great varieties of climates comprised in this division might be sub-divided into many groups, according to meteorological characters and therapeutical effects on invalids, but considering the great drawbacks of all classifications we humbly resign ourselves to two rather primitive sub-divisions." H. Weber, *Book of Health*, Article 'Climates and Health Resorts.'

† Especially that by Hermann Weber, *op. cit.*, and by the same author in Ziemssen's *Hand-book of Therapeutics*.

suitable for a person suffering from chronic bronchitis may be extremely unsuitable for a case of rheumatism, and so on. And this question has a double aspect, for, on the one hand, a patient already afflicted may be specially ordered to leave one place and to go to another for the purpose of arresting or lessening his disease—the therapeutic use of climate in an individual case—whilst on the other hand careful study of the relationship between the climatic factors of any locality and its prevalent diseases may demonstrate the liability of the inhabitants of that locality to particular diseases at certain seasons, according as one factor, such as temperature, humidity, etc., is specially prominent—the study of the seasonal prevalence of disease amongst the population generally—a most important but very complex question.* As stated before,† the study of the seasonal prevalence of diseases in India, and their correlation with other factors, is worthy of far more systematic study, and of official help and encouragement towards the same, than have yet been accorded to it.

Climates of India.—Only a very brief summary of the chief climates in India proper can be given here; for fuller information the student must consult the excellent works of Blandford—from which the following tables and most of the information are derived—of MacNamara, Fayrer, Baikie, Lord, Moore, and others.

The first point, which will not be unexpected by any one who has studied the remarks previously made on the geography and physiography of India, is the wonderful variety of the climates in this country. "Northern or extra-tropical India alone, in its most easterly and most westerly provinces, in Assam on the one hand and in Sindh

* Dr. A. Buchan, a very able and competent authority, has taken up this difficult subject, in connection with the health of London, and has found it necessary to divide the year into six periods of which the first is characterised by dampness and cold; the second by cold; the third by dryness and cold; the fourth by dryness and warmth; the fifth by heat; and the sixth by dampness and warmth; and for each of these there are certain diseases which are specially prevalent and give rise to the greater part of the mortality during those seasons. v. *San. Record* for 19th August, 1893.

† v. p. 327.

on the other, present us with the greatest possible contrast of dampness and dryness, a contrast greater than that of the British Isles and Egypt; and when, further, we compare the most northerly province, the Punjab, with the most southerly, such as Travancore or Tenasserim, we have in the former a continental climate of the most pronounced character, extreme summer heat alternating with winter cold that sometimes sinks to the freezing point, and in the latter that almost unvarying warmth in conjunction with a uniformly moist atmosphere, that is especially characteristic of the shores of a tropical sea. To speak, then, of the climate of India as we might speak of the climate of Ireland, as if such expression denoted certain definite conditions of heat and moisture, varying only within moderate limits, and nearly uniform in the several provinces, would be as misleading as if we were to speak of its inhabitants in terms implying that they are a homogeneous race, alike in ethnic and social characters, culture and belief."*

It is probable that these varied climates of India could be arranged with considerable accuracy under the three headings of (1) Island climates; (2) Continental (or Inland) climates; and (3) Hill climates, but no rigid classification under any system will be here attempted, and, with the exception of a general description of the climates of hill stations, the remainder will be arranged according to locality, proceeding from north to south, with tables giving the meteorological data of one or more representative stations within each area.

The Hill Climates of India are in general damper and cooler than those of the neighbouring plains, and as a consequence, are specially acceptable to robust and healthy Europeans and to those who are simply suffering from the debility following upon long residence in the plains. Certain of them, such as Ootacamund, Wellington, Simla, etc., are above the level of malaria, whilst others, such as

* Blanford.

Yercaud, Pachmari, Mount Abu, etc., are either known or suspected to be below it. This is a most important matter and demands very careful attention in the selection of any fresh hill station. With regard to the real hill sanitaria situated at a level of 5,000 feet and upwards, they are suitable, as before stated, for those suffering from malaria, or from general debility following acute disease or hard work in the plains, and they form delightful places of resort to those who can obtain leave. But cases in which there are serious organic lesions of the cerebral, thoracic, or abdominal viscera, are quite unsuitable, and such should be retained under medical treatment till strong enough to travel and then sent for a change to England or Southern Europe.

Between the climates of the sanitaria on the Himálayas and Nilgiris there is one very marked difference. At the former the weather is perfect for some months, extremely cold and wet during others, whilst at the latter, the climate is far more equable and the rainfall more evenly distributed throughout the year. The climate of the Niligris is the nearest approach to that of S. England to be found in India.* For the thinly-clad and poorly-nourished Hindu the climates of the hill stations are far from attractive, and many of them die of pneumonia, dysentery, etc., but others with stronger bodies and in easy circumstances soon become used to the lowered temperature and feel a vigour of mind and body much beyond that to which they are accustomed. The following tables will repay careful perusal, illustrating as they do the chief climatic features of four very different hill stations. Shillong has been chosen in place of Darjiling as likely to prove much the more important sanitarium (*v.* tables 1—4).

The climate of the Punjab is characterised by an alternation of decided hot and cold seasons, and by a light rainfall, which latter, however, varies very much in amount

* "Among all the pleasant memories of more than 30 years of Indian life, and an experience of all parts of the empire from Peshawar to Sibsagar and Point de Galle, I can recall no more charming scene and climate than those of the Nilgiri Hills." Blandford.

in different years and in different parts of the same province. Lahore is chosen as a fairly representative station (*v.* table 5).

Sindh, the "great plain traversed by the Lower Indus from the Punjab frontier to the sea, is at once the driest and, as a whole, the hottest of all the provinces in India." Jacobabad (*v.* table 6) is the hottest and driest of the principal towns, Hyderabad, situated in a very exposed position, is a little moister and cooler, and Karachi within 8 miles of the sea, is the coolest of all.

The climate of Rajputana is intermediate between that of Sindh and the Central Indian Plateau, and the hot and cold seasons are not so strongly contrasted as in the Punjab.

Coming next to the North-West Provinces and Oudh, formed by the great alluvial valley through which run the Jumna and Ganges with their numerous tributaries, and which extends to Behar in Bengal, we find, as might be expected, a remarkably rich and fertile tract of country in which are situated many very important towns. The climate is different in many ways from that of the Punjab on the west and of Bengal on the east. The cold season is well marked, but not so much as in the Punjab, and it is also less rainy and cloudy. In March strong and very dry* west winds begin to blow. In May these are sometimes tempered by slight showers of rain—the so-called *choti bursàt.* Towards the end of June the rains begin, and wet days alternate with 'breaks' of moist and steamy weather till September, when they cease. The most remarkable climatic peculiarity of the North-West Provinces is the liability of the rainfall to fail almost completely in any year, especially in the Gangetic plain (*doab*) proper. The disastrous effects of this are guarded against, so far as possible, by the Ganges Canal—the greatest irrigation canal in the world—but in spite of this the liability of the district to suffer from severe famine, though greatly lessened, as compared with former times, continues (*v.* table 7).

* The relative humidity may sink to as low as 6 *per cent.*

HILL STATIONS.

1. Leh—Elevation 11,503 feet.

—	Temperature. Mean.	Temperature. Mean Max.	Temperature. Mean Min.	Temperature. M. Range. Daily.	Temperature. M. Range. Month.	Hum. Mean.	Cloud. Mean.	Rainfall. Ins.	Rainfall. Days.	Barometer. Mean.	Barometer. Daily Range.
January	18	35	11	25	44	61	6·4	0·2	4	19·64	·07
February	19	35	9	26	48	61	6·7	0·2	5	·58	·08
March	31	46	20	26	50	56	6·5	0·2	2	·67	·08
April	41	57	31	26	43	42	6·4	0·1	1	·67	·08
May	47	64	36	27	44	40	6·5	0·1	2	·68	·08
June	56	74	44	30	50	37	4·9	0·2	1	·64	·09
July	62	80	51	29	44	44	5·1	0 5	3	·60	·10
August	60	80	50	30	45	48	5·1	0·4	3	·63	·11
September	52	72	42	30	46	44	4·0	0·2	1	·69	·11
October	40	59	30	29	47	41	3·9	0 5	...	·73	·10
November	30	47	20	27	43	50	4·0	0	...	·72	·09
December	23	39	13	26	41	58	5·3	0·1	2	·70	·08
	40					49	5·4	2·7	24	19·66	

Mean highest temperature of year	90°
,, lowest ,, ,,	– 4°
,, annual range of temperature	94°
Highest recorded reading (10 years)	93° (1876)
Lowest ,, ,, ,,	–17° (1878)

Absolute range of temperature	110°
Rainfall of wettest year (11 years)	5·4″ (1879)
,, driest ,, ,,	0·4″ (1876)
Rainy days in wettest year (8 yrs.)	43 (1886)
,, ,, driest ,, ,,	8 (1878)

HILL STATIONS.

2. SIMLA—Elevation 7048 feet.

	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean. Max.	Mean, Min.	M. Range. Month.	M. Range. Daily.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	41	54	38	16	36	58	5·0	2·8	3	23·29	·06
February	41	53	36	17	34	56	5·0	2·7	5	·24	·05
March	50	63	45	18	40	53	5·0	3·0	6	·27	·05
April	58	72	52	20	38	51	4·6	2·8	6	·26	·05
May	64	77	57	20	39	49	4·1	4·7	9	·22	·05
June	67	79	61	18	36	64	6·1	7·9	10	·15	·05
July	64	73	61	12	22	88	8·5	19·3	21	·12	·05
August	63	71	60	11	20	91	8·6	18·1	22	·16	·05
September	61	72	58	14	23	82	6·2	6·0	12	·25	·05
October	56	68	51	17	28	53	1·0	1·4	2	·33	·06
November	49	61	43	18	31	50	1·5	0·3	1	·32	·06
December	45	57	40	17	30	47	3·5	1·1	2	·31	·06
Year... ...	55					62	4·9	70·1	99	23·24	

Mean highest temperature of year 88°
,, lowest ,, ,, 25°
,, annual range of temperature 63°
Highest recorded reading (11 years) 94·4° (1879)
Lowest ,, ,, ,, 19·7° (1883)

Absolute range of temperature 74·7°
Rainfall of wettest year (24 years) 94·9″ (1864)
,, driest ,, ,, 52·1″ (1867)
Rainy days in wettest year (12 years) 136 (1884-1885)
,, driest ,, ,, 74 (1877)

HILL STATIONS.

3. Shillong—Elevation 4792 feet (4 years).

—	Temperataure.					Hum.	Cloud.	Rainfall.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.
January	51	62	42	20	31	70	2·5	0·4	1
February	54	64	46	18	30	65	3·4	0·8	4
March	62	71	54	17	32	59	3·1	2·0	5
April	65	74	58	16	29	65	5·2	3·7	11
May	68	76	63	13	22	77	6·6	10·0	21
June	69	76	65	11	18	84	7·8	17·0	24
July	69	76	66	10	16	87	8·6	14·0	22
August	69	76	65	11	17	88	8·5	14·4	23
September	67	74	64	10	20	89	8·1	15·4	22
October	63	72	58	14	25	86	6·2	6·2	13
November	57	66	49	17	30	76	3·4	1·0	3
December	51	61	42	19	31	75	3·2	0·4	1
Year...	62					77	5·6	85·3	150

Mean highest temperature of year . . .	82°	Absolute range of temperature . .	51·5°
„ lowest „ „ . . .	34°	Rainfall of wettest year (20 years) .	121·2″ (1867)
„ annual range of temperature . .	48°	„ driest „ „ .	53·6″ (1873)
Highest recorded reading (4 years). . .	84° (1872)	Rainy days in wettest year (18 years)	191 (1883, 1884)
Lowest „ „ „ . . .	32·5° (1872)	„ driest „ „	109 (1868)

HILL STATIONS.

4. OOTACAMUND—Elevation 7252 feet (13 months).*

	Temperature.					Hum.	Cloud.	Rainfal.		Barometer.	
—	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	48	66	35	31	44	55	1·9	0·5	1	23·20	·06
February	51	68	39	29	42	61	4·2	0·2	...	·22	·07
March	55	71	44	27	45	46	3·3	1·2	1	·23	·08
April	58	72	51	21	29	64	5·6	3·9	11	·20	·08
May	59	71	53	18	31	70	6·4	6·2	16	·16	·09
June	56	65	53	12	23	84	8·7	6·0	17	·13	·06
July	55	62	52	10	20	84	9·2	5·6	23	·14	·05
August	55	63	51	12	24	82	8·6	4·2	19	·14	·07
September	55	63	50	13	25	79	8·0	3·7	13	·16	·07
October	54	64	50	14	24	89	8·7	9·8	22	·21	·09
November	53	63	47	16	35	90	6·7	2·9	16	·20	·07
December	51	64	42	22	35	71	4·9	1·6	4	·18	·07
Year... ...	55					71	6·3	45·8	143	23·18	

Highest recorded temperature ... 77·3°
Lowest " " ... 25·3°
Range during year ... ... 52°

Rainfall of wettest year (10 years) 58·4″ (1830)
" driest " " 33·7″ (1867)

* The rainfall is the mean of 11 years.

THE PUNJAB.

5. Lahore—Elevation 732 feet.

	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	54	68	43	25	39	60	3·2	0·7	2	29·34	·08
February	59	71	46	25	32	57	3·4	1·1	3	·28	·08
March	69	83	57	26	48	48	3·1	1·1	2	·18	·08
April	81	95	66	29	48	37	2·5	0·6	3	·05	·09
May	88	102	73	29	48	33	2·4	0·9	3	28·92	·08
June	93	107	81	26	45	37	2·9	1·8	3	·77	·09
July	89	99	81	18	39	58	4·2	7·4	7	·78	·09
August	88	98	80	18	32	61	3·7	4·6	6	·85	·09
September	85	97	75	22	34	55	1·7	2·4	4	·97	·09
October	77	93	62	31	46	46	0·8	0·6	1	29·15	·08
November	64	81	49	32	48	47	1·2	0·2	1	·30	·08
December	55	71	43	28	41	56	2·0	0·5	2	·35	·08
Year... ...	75					50	2·6	21·9	37	29·08	

Mean highest temperature of year . 117°
„ lowest „ „ . 34°
„ annual range of temperature . 83°
Highest recorded reading (11 years) . 120·3° (1879)
Lowest „ „ „ . 29·8° (1878)

Absolute range of temperature . . 90·5°
Rainfall of wettest year (27 years) . 37·8″ (1875)
„ driest „ „ . 8·7″ (1871)
Rainy days in wettest year (12 years) 47 (1881)
„ „ driest „ „ 26 (1875)

SINDH.

6. Jacobabad—Elevation 186 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	57	74	43	31	48	46	2·4	0·2	1	29·89	·12
February	62	77	48	29	51	39	3·2	0 2	2	·82	·12
March	74	90	60	30	54	41	3·3	0·3	1	·70	·13
April	83	99	68	31	51	38	3·1	0·2	1	·56	·13
May	91	108	76	32	50	36	1·4	0·1	1	·42	·12
June	96	111	83	28	44	42	1·1	0·1	...	·26	·12
July	94	107	83	24	37	53	2·2	1·4	3	·24	·12
August	91	103	81	22	33	58	2·4	1·4	4	·33	·11
September	88	101	76	25	39	55	0 9	0·3	...	·47	·11
October	78	96	63	33	51	46	0·4	...	...	·67	·11
November	65	84	50	34	52	45	0·9	0·1	...	·82	·11
December	58	75	43	32	47	48	1·8	0·1	...	·90	·12
Year	78					46	1·9	4·4	13	29·59	

Mean highest temperature of year . 118°
„ lowest „ „ . 32°
Mean annual range of temperature . 86°
Highest recorded reading (9 years) 120·9° (1882)
Lowest „ „ „ 29·2° (1881)

Absolute range of temperature . 91·7°
Rainfall of wettest year (26 years) 12·1″ (1869)
„ driest „ „ 0·7″ (1881)
Rainy days in wettest year (9 yrs) 35 (1878)
„ „ driest „ „ 5 (1880)

N.W.P. AND OUDH.

7. LUCKNOW—Elevation 369 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	61	74	46	28	42	59	2·7	0·8	2	29 68	·11
February	66	78	50	28	47	52	3·0	0·3	2	·61	·11
March	77	91	61	30	52	43	2·7	0·3	1	·50	·11
April	87	101	71	30	47	35	2·1	0·1	1	·37	·11
May	92	104	76	28	44	42	2·0	0·9	2	·27	·12
June	92	103	82	21	38	54	4·7	5·0	7	·15	·11
July	86	93	80	13	26	74	7·7	10·8	16	·15	·10
August	85	92	79	13	23	77	7·4	10·4	15	·22	·10
September	85	93	77	16	27	72	5·4	7·1	9	·31	·11
October	79	91	65	26	42	60	1·5	1·4	1	·50	·11
November	69	83	52	31	44	53	0·8	...	...	·63	·11
December	61	75	45	30	41	58	1·8	0·5	1	·69	·11
Year... ...	78					57	3·5	37·6	57	29·42	

Mean highest temperature of year . . 114°
" lowest " " . . 38°
" annual range of temperature. . 76°
Highest recorded reading (10 years) . 117·3° (1878)
Lowest " " " . 34·4° (1878)

Absolute range of temperature . . 82·9°
Rainfall of wettest year (20 years) . . 64·9″ (1871)
" driest " " . . 14·4″ (1877)
Rainy days in wettest year (14 years) . 77 (1874)
" " driest " " . 27 (1876)

The Central Indian Plateau has been alluded to in the short description of the physiography of the country already given. In many parts the climate is very pleasant and the stations healthy. During the cool season, from November to the end of February, the weather is delightful, especially towards the eastern part of the plateau, between Jabalpur and Benares (*v.* table 8).

The climate of Behar, a densely populated and highly cultivated province, is intermediate between that of the N.W.P. and Lower Bengal, but is more akin to the former. The rainfall is moderate and the cold weather pleasant. The climate of Chutia Nagpur is much the same, the rain-fall being slightly heavier than in most parts of Central India.

The provinces of Bengal and Orissa are largely made up of the deltas of the Brahmaputra, Ganges, Mahanadi and other rivers. "Intersected by innumerable river channels and abounding in swamps, while open to the damp winds from the bay, which begin to blow on the coast as early as February and gradually penetrate farther inland with the increasing heat, the climate of Bengal is as characteristically damp and relaxing as that of North-Western India is the reverse. The dry westerly winds that play so great a part in the meteorology of the Upper Provinces are felt only occasionally and intermittently in the province of Bengal, during the spring months and chiefly in the warmest hours of the day, and even then with a reduced temperature and of a less parching character, owing to the moisture taken up from the surface over which they blow. The customary division of the year into three seasons, the cool season, the hot season, and the rains, holds good in Bengal as in the more westerly provinces, but the first is shorter and less bracing, and the heat of the second, if less intense, owing to the greater dampness of the air, is on this account, perhaps, more trying to the European constitution. The rains are also longer and more copious." The climate of Calcutta (*v.* table 9) is fairly typical of Bengal generally.

CENTRAL INDIAN PLATEAU.

8. Saugor—Elevation 1769 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	63	77	51	26	40	46	1·4	0·6	2	28·24	·10
February	67	81	54	27	43	39	1·5	0·5	1	·18	·11
March	78	93	64	29	41	32	1·3	0·2	...	·11	·11
April	85	101	72	29	39	28	1·4	0·2	1	·02	·11
May	89	104	76	28	39	28	2·0	0·6	3	27·92	·11
June	85	100	77	23	37	50	4·1	6·3	11	·82	·10
July	78	86	74	12	24	77	6·1	16·8	19	·80	·09
August	77	85	73	12	20	83	5·9	11·2	18	·86	·09
September	77	87	71	16	26	78	4·3	7·3	12	·95	·10
October	75	87	66	21	33	55	1·4	1·3	2	28·12	·10
November	69	82	56	26	36	42	1·0	0·4	...	·20	·10
December	64	76	51	25	38	45	1·0	0·7	1	·24	·10
Year	76					50	2·6	46·1	70	28·04	

Mean highest temperature of year.	110°	Absolute range of temperature . .	71·3°
,, lowest ,, ,, .	42°	Rainfall of wettest year (31 years) .	70·1″ (1867)
,, annual range of temperature	68°	,, driest ,, ,, .	22·1″ (1848)
Highest recorded reading (8 years)	111·4° (1881)	Rainy days in wettest year (11 years)	106 (1884)
Lowest ,, ,, ,, .	40·1° (1883)	,, ,, driest ,, ,, .	56 (1879, 1880)

BENGAL AND ORISSA.

9. Calcutta—Elevation 21 feet.

—	Temperature. Mean.	Temperature. Mean Max.	Temperature. Mean Min.	Temperature. M. Range. Daily.	Temperature. M. Range. Month.	Hum. Mean.	Cloud. Mean.	Rainfall. Ins.	Rainfall. Days.	Barometer. Mean.	Barometer. Daily. Range.
January	65	77	55	22	33	71	1·4	0·4	2	30·02	·13
February	70	82	61	21	37	69	2·2	1·0	3	29·95	·13
March	79	91	70	21	38	69	2·2	1·3	3	·86	·14
April	85	96	76	20	33	71	2·8	2·3	5	·75	·14
May	85	94	77	17	30	76	4·4	5·6	10	·66	·12
June	84	91	79	12	25	84	7·0	11·8	18	·55	·10
July	83	88	78	10	17	87	8·1	13·0	24	·54	·09
August	82	87	78	9	16	89	8·2	13·9	24	·60	·10
September	82	87	78	9	17	88	7·1	10·0	18	·68	·11
October	80	87	75	12	23	83	4·2	5·4	8	·83	·11
November	72	82	64	18	29	74	2·4	0·6	2	·96	·12
December	65	76	56	20	31	72	2·0	0·3	1	30·02	·13
Year	78					78	4·3	65·6	118	29·78	

Mean highest temperature of year . . 102°
,, lowest ,, ,, . . 48°
,, annual range of temperature . . 54°
Highest recorded reading (8 years) . . 105·3° (1879, 1885)
Lowest ,, ,, ,, . . 45° (1878)

Absolute range of temperature . . . 60·3°
Rainfall of wettest year (57 years) . . 93·3″ (1871)
,, driest ,, ,, . . 43·6″ (1837)
Rainy days in wettest year (34 years) . 154 (1861)
,, ,, driest ,, ,, . . 72 (1853)

Assam, including Cachar, Sylhet, and certain hill tracts on the Indo-Burmese frontier, consists of two main alluvial plains through which run the Brahmaputra, Baràk and smaller rivers, and of the aforesaid hills—the Khasi, Naga, Lushai and Manipur ranges, etc. The greater part of the province still consists of jungle and swamps, but large areas, such as the plain of Sylhet, have been cultivated for a long time, whilst other parts, in Assam proper and Cachar especially, have been cleared of jungle and its place taken by numerous tea gardens. The soil is extremely fertile, the natural products valuable, and the zoology and botany very varied, but these very qualities, the result of a heavy rainfall combined with the physical features, made the province an extremely unhealthy one to the pioneers of civilisation. "The European pioneers of tea planting in the Darjiling and Bhutan terai suffered severely; many perished from malarious fever and its sequelæ, and from the non-observance of approved dietetic, hygienic and sanitary principles. But now that ever-increasing areas are being denuded of forest, of rank and impenetrable jungle, and reduced to a state of good husbandry and cultivation; that the evils of intemperance in eating and drinking are better understood, and avoided accordingly; that drinking water is purified by boiling and filtration; that sleeping accommodation is provided in rooms well raised above the ground—in the most elevated portion of the estate—sometimes on adjoining spurs, at a considerable height; that the dry, or dry-earth system of conservancy is enforced; that the head and spine are thoroughly protected from the direct action of the sun; that woollen under-clothing is worn at all seasons; and that prophylactic doses of quinine are often employed during the malarious months; tea planting, if not quite so healthy as occupations in other localities on the plains, is nevertheless profitably carried on by Europeans on terai land where only a few years ago, under the old conditions of jungle, forest, swamp and waste, their lives could scarcely have been maintained throughout a single cycle of

ASSAM.

10. Silchar—Elevation 104 feet.

	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
				M. Range.							
	Mean.	Mean. Max.	Mean, Min.	Daily.	Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	64	77	52	25	35	75	2·7	0·6	2	29·94	·13
February	67	79	55	24	38	70	3·1	2·6	6	·89	·13
March	73	85	63	22	36	72	4·0	7·9	12	·81	·14
April	78	87	69	18	30	76	5·1	13·0	17	·72	·14
May	80	87	72	15	30	81	6·1	15·7	19	·65	·13
June	82	89	76	13	24	85	7·5	19·1	22	·54	·11
July	82	89	77	12	21	85	7·6	20·6	25	·53	·12
August	82	89	77	12	22	86	7·6	18·2	23	·58	·13
September	82	89	76	13	24	84	6·9	14·2	19	·66	·13
October	80	88	72	16	28	81	4·6	6·4	9	·78	·13
November	73	84	64	20	32	77	3·2	1·0	2	·88	·12
December	66	78	55	23	36	76	2·8	0·7	1	·94	·13
Year... ...	76					79	5·1	120·0	159	29·74	

Mean highest temperature of year . . 99°
,, lowest ,, ,, . . 45°
,, annual range of temperature . . 54°
Highest recorded reading (11 years) . 101·8° (1886)
Lowest ,, ,, ,, . . 43° (1880)

Absolute range of temperature . . . 58·8°
Rainfall of wettest year (29 years) . . 188·2″ (1866)
,, driest ,, ,, . . 65·3″ (1863)
Rainy days in wettest year (18 years) . 187 (1874)
,, driest ,, ,, . . 137 (1882)

the seasons, and would not have been worth more than one year's purchase."* In addition, the sanitary condition of the general population, and of the imported coolies employed in the tea gardens, has received a good deal of attention from the Government and planters, so that, though far from perfect, it is infinitely better than formerly. The mortality and disablement from malaria disease is still enormous, and will remain so for many years; whilst the deaths from cholera, intestinal parasites and other diseases are excessive.†

The climate varies considerably in different parts. Allusion has already been made to the enormous rainfall at Cherra Punji‡ and details of the hill station of Shillong (*v.* table 3) have been given. For the lower altitudes the climate of Silchar is fairly representative (*v.* table 10).

The Central Provinces are made up chiefly of the three great plains of Berar, Nagpur, and Raipur (Chhatisgarh), which stretch away south from the foot of the Satpura range and are drained respectively by the Poorna, a tributary of the Tapti, the Waigunga, a tributary of the Pranhita and Godaveri, and the Mahanadi. These plains, composed of black cotton soil, are cultivated in parts, clothed with scrub jungle in other parts, and to a slight extent with forest, the latter being a Government reserve and encouraged to spread as rapidly as possible. In some respects the climate may be considered as representative of India: the hot, rainy, and cool seasons are well marked, and camp life during the last season, from November till the end of February, is as perfect as can be imagined (*v.* table 11). The most unhealthy season, as in most other parts of India, is during the period between the cessation of the rains and the commencement of the cold weather. The climate of the stations situated upon the various hill ranges—Chindwara, Seoni, Betùl, Pachmari, etc.,—is reasonably cool. Thus, at Seoni, the mean temperature for November, December and January is 64° F., and for the year 74° F.

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* *v. I. M. G.*, Oct., 1893, p. 359. † Sir J. Fayrer. ‡ *v.* p. 326.

CENTRAL PROVINCES.

11. NAGPUR—Elevation 1025 feet.

	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
—	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	69	83	55	28	42	51	2·2	0·6	1	28·97	·14
February	73	89	59	30	46	42	2·0	0·4	2	·91	·14
March	82	99	67	32	49	32	2·5	0·6	2	·83	·15
April	89	105	75	30	42	28	3·1	0·5	2	·73	·15
May	93	108	80	28	42	30	4·1	0·8	4	·64	·14
June	86	98	78	20	38	60	7·1	8·8	15	·56	·11
July	79	88	75	13	25	80	8·6	13 3	20	·56	·10
August	79	88	75	13	23	78	8·3	8·9	18	·61	·11
September	79	89	73	16	24	76	7·4	7·8	15	·67	·12
October	77	90	68	22	35	60	4·0	2·3	3	·82	·12
November	71	84	59	25	39	52	2·6	0·4	1	·94	·12
December	67	80	54	26	38	52	2·4	0·5	1	·98	·12
Year... ...	79					53	4·5	44·9	84	28·77	

Mean highest temperature of year	115°
,, lowest ,, ,,	46°
,, annual range of temperature	69°
Highest recorded reading (10 years)	117·7° (1883, 1885)
Lowest ,, ,, ,,	43·1° (1883)
Absolute range of temperature	74·6°
Rainfall of wettest year (39 years)	65·3″ (1831)
,, driest ,, ,,	25·5″ (1868)
Rainy days in wettest year (13 years)	119 (1884)
,, ,, driest ,, ,,	61 (1876)

The West Coast of the peninsula, from the gulf of Cambay to Cape Comorin, more especially the belt of land extending from the western slope of the Ghâts to the Sea (Konkan and Malabar), is noteworthy as having a climate at once the dampest and most uniform in India. Although the area included runs from 8°—21° N. lat., the mean annual temperature is almost the same throughout, but the extremes are greater in the north, *e.g.*, at Surat, and diminish by degrees, till at Cochin the mean temperature for January, *viz.* 79° F., is two degrees higher than that of July, the difference being probably due to the smaller rainfall and lesser degree of humidity in the former month. The climate of Mercara, in Coorg, is that of the summit of the Ghâts and is distinguished by its enormous rainfall and high degree of cloudiness* and humidity. The important, but very malarious, district of the Wynaad is situated on the Ghâts immediately to the south of Mercara, and runs down to the foot of the hills. The climate is similar to that of Coorg but slightly warmer owing to its lower elevation. Bombay (*v.* table 12) is fairly representative of the climate of the W. Coast, the extremes being Surat in the north and Cochin in the south, as already explained.

Within a distance of less than fifty miles from the eastern slope of the Ghâts the heavy rainfall that deluges the west-coast is almost entirely unknown.† From the Ghâts there slopes a vast tableland eastwards drained by the Godaveri, Kistna, Cauvery and other rivers which discharge their waters into the Bay of Bengal. To the south and south-east of Bellary is a large tract of 6,000—7,000 square miles, on which the mean annual rainfall is less than 20 inches. This district has frequently suffered from dire famine, the last occurring as late as 1892. It is not to be understood, however, that the climate of this great plateau, which includes Khandesh, the Deccan, and Mysore, is unhealthy—or even unpleasant—throughout, for though there are certain parts where malarious fevers are very preva-

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* *v.* p. 324.

† *v.* p. 330, *para.* 2.

THE WEST COAST.

12. BOMBAY—Elevation 37 feet.

	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	74	82	68	14	24	70	1·5	0·1	1	29·95	·12
February	75	82	69	13	26	69	1·3	...	1	·92	·12
March	79	85	74	11	22	73	1·8	...	...	·88	·12
April	82	88	77	11	17	75	2·3	...	...	·81	·11
May	85	90	80	10	15	75	4·1	0·5	2	·77	·10
June	83	88	80	8	17	82	7·9	20·8	20	·67	·08
July	81	85	77	8	13	87	9·1	24·7	29	·67	·06
August	80	84	77	7	13	87	8·8	15·1	26	·73	·08
September	80	84	76	8	13	86	7·5	10·8	21	·78	·09
October	81	87	76	11	18	81	4·3	1·8	7	·84	·11
November	80	86	73	13	22	71	2·2	0·5	1	·91	·11
December	76	84	70	14	23	70	1·8	0·1	...	·95	·12
Year	80					77	4·4	74·4	108	29·82	

Mean highest temperature of year . . .	95°	Absolute range of temperature	46·9°
,, lowest ,, ,, . . .	61°	Rainfall of wettest year (40 years) . .	114·9″ (1849)
,, annual range of temperature . .	34°	,, driest ,, ,, . . .	40·6″ (1871)
Highest recorded reading (37 years) . .	100·2° (1857)	Rainy days in wettest year (11 years) . .	123 (1883)
Lowest ,, ,, ,, . . .	53·3° (1847)	,, driest ,, ,, . .	82 (1876)

S. INDIAN PLATEAU.

13. Poona—Elevation 1849 feet.

—	Temperature. Mean.	Temperature. Mean Max.	Temperature. Mean Min.	Temperature. M. Range. Daily.	Temperature. M. Range. Month.	Hum. Mean.	Cloud. Mean.	Rainfall. Ins.	Rainfall. Days.	Barometer. Mean.	Barometer. Daily Range.
January	72	86	54	32	43	41	1·8	0·2	1	28·13	·14
February	76	90	56	34	50	33	1·7	...	...	·09	·14
March	83	98	64	34	47	29	2·5	0·2	1	·05	·14
April	86	101	69	32	43	31	2·4	0·6	2	27·99	·14
May	85	100	71	29	41	42	3·0	1·6	2	·94	·12
June	79	89	72	17	27	69	7·6	5·6	13	·88	·09
July	75	81	70	11	19	79	9·0	6·6	21	·87	·07
August	75	83	69	14	22	79	8·7	4·1	20	·91	·08
September	75	83	68	15	23	77	8·1	4·3	15	·97	·10
October	78	87	66	21	33	58	4·9	4·1	8	28·05	·12
November	75	85	59	26	41	46	2·8	0·8	2	·10	·13
December	72	83	54	29	41	41	2·7	0·2	1	·14	·13
Year	78					52	4·6	28·3	86	28·01	

Mean highest temperature of year . . .	106°	Absolute range of temperature . . .	68·4°
,, lowest ,, ,, . . .	44°	Rainfall of wettest year (43 years) . . .	56·9″ (1861)
,, annual range of temperature . . .	62°	,, driest ,, ,, . . .	14·2″ (1844)
Highest recorded reading (8 years) . . .	109·2° (1886)	Rainy days in wettest year (11 years) . .	94 (1883)
Lowest ,, ,, ,, . . .	40·8° (1881)	,, ,, driest ,, ,, . . .	71 (1876)

S. INDIAN PLATEAU.

14. Bangalore—Elevation 2981 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	67	79	56	23	33	60	2·8	0·2	1	27·04	·12
February	72	85	59	26	36	52	2·3	0·1	...	·02	·13
March	77	90	64	26	37	49	2·6	0·6	2	26·99	·13
April	80	93	69	24	32	52	3·5	1·3	3	·94	·13
May	79	92	69	23	33	61	4·5	5·0	10	·90	·12
June	74	85	67	18	27	73	5·7	3·2	13	·88	·10
July	72	83	66	17	24	77	6·2	4·0	14	·89	·09
August	72	83	66	17	24	77	6·1	5·9	17	·90	·11
September	72	82	65	17	25	76	5·9	6·3	13	·93	·12
October	72	82	65	17	24	75	5·7	6·4	13	·96	·12
November	70	79	62	17	27	73	4·9	1·9	7	27·00	·12
December	67	78	59	19	29	68	4·0	0·7	3	·04	·12
Year	73					66	4·5	35·6	96	26·96	

Mean highest temperature of year . . .	98°	Absolute range of temperature . . .	53·6°
,, lowest ,, ,, . . .	51°	Rainfall of wettest year (51 years) . .	56·7″ (1874)
,, annual range of temperature . . .	47°	,, driest ,, ,, . . .	16·0″ (1838)
Highest recorded reading (10 years) . . .	99·4° (1882)	Rainy days in wettest year (11 years.) . .	149 (1878)
Lowest ,, ,, ,, . . .	45·8° (1877)	,, ,, driest ,, ,, . . .	73 (1876)

lent and others where the heat is excessive, many of the healthiest and most favourite stations in India are here situated, such as Poona, Belgaum and Bangalore (*v.* tables 13, 14). In the southern portion of the plateau, especially Mysore, the rainfall is sufficient to permit of the growth of large forests of teak, sandal wood and other valuable trees, but the jungles are extremely malarious and the inhabitants suffer severely. Poona and Bangalore are chosen as examples not so much for their representative climatic characters as for their importance. The former station forms a delightful retreat, during the rains, for dwellers in the western presidency who object to the excessive moisture of Bombay and other places, whilst the climate of Bangalore* is the finest of any so-called 'plain' station in India.

Coming, lastly, to the Carnatic, which forms the eastern and south-eastern boundaries of the great plateau just described, and includes the country drained by the lower portion of the Cauvery, and the numerous hill-ranges of Southern India, we have a climate which presents important differences to those of other parts of India. What this difference is can easily be understood from a study of the geographical position of this portion of the peninsula and from the descriptions already given of its rainfall,† and of its relation to the summer and winter monsoons.‡ It is not so uniform a climate as that of the west coast, but, on the other hand, it is rarely very hot and never very cool. The most unpleasant months are April, when the damp and relaxing 'long-shore' winds blow, and August and September, when it is very close and 'muggy' before the advent of the winter monsoon. For the ordinary European it is a wonderfully healthy climate, but to some it is too relaxing, whilst for others, who are accustomed to the cloudy and rainy west coast, it is too warm. The town of Madras (*v.* table 15) has a climate fairly typical of the Carnatic generally, but in the interior of the country (*v.* table 16) it is drier and less relaxing.

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* "A climate second only in attractiveness to that of the Nilgiri hills." Blandford. † *v.* pp. 330-1. ‡ *v.* p. 373.

THE CARNATIC.

15. Madras—Elevation 22 feet.

—	Temperature.			M. Range.		Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	Daily.	Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	76	85	68	17	26	72	4·1	0·9	3	29·99	·12
February	77	87	68	19	28	71	2·8	0·3	1	·97	·13
March	81	90	72	18	29	73	2·5	0·4	1	·91	·14
April	85	93	77	16	27	72	2·9	0·6	1	·82	·13
May	87	98	81	17	32	67	3·9	2·1	3	·74	·13
June	88	99	81	18	31	61	6·5	2·1	10	·70	·12
July	86	97	79	18	28	64	7·1	3·9	14	·72	·12
August	85	95	77	18	27	69	6·4	4·6	14	·75	·13
September	84	94	77	17	28	70	6·2	4·8	11	·77	·13
October	81	89	75	14	25	77	6·2	10·5	14	·84	·13
November	78	85	72	13	25	79	6·3	13·5	14	·92	·12
December	76	83	70	13	23	77	5·4	5·3	9	·98	·11
Year... ...	82					71	5·0	49·0	95	29·84	

Mean highest temperature of year . . .	108°	Absolute range of temperature . . .	55·3°
„ lowest „ „ . . .	60°	Rainfall of wettest year (74 years) . .	88·4″ (1827)
„ annual range of temperature. . . .	48°	„ driest „ „ . . .	18·5″ (1832)
Highest recorded reading (27 years) . .	112·9° (1880)	Rainy days in wettest year (26 years) . .	119 (1847)
Lowest „ „ „ . . .	57·6° (1876)	„ „ driest „ „ . .	73 (1876)

THE CARNATIC.

16. TRICHINOPOLY—Elevation 275 feet.

—	Temperature. Mean.	Temperature. Mean Max.	Temperature. Mean Min.	M. Range. Daily.	M. Range. Month.	Hum. Mean.	Cloud. Mean.	Rainfall. Ins.	Rainfall. Days.	Barometer. Mean.	Barometer. Daily Range.
January	76	87	67	20	30	68	4·2	1·0	1	29·71	·14
February	78	92	68	24	34	62	2·9	0·5	...	·70	·16
March	83	98	73	25	36	58	3·1	0·7	1	·66	·16
April	87	101	78	23	33	54	4·4	1·8	1	·57	·16
May	88	102	78	24	33	56	5·6	3·8	5	·52	·15
June	86	99	78	21	29	57	7·4	1·3	3	·50	·12
July	85	98	78	20	27	57	7·7	2·2	3	·51	·12
August	84	96	76	20	28	61	7·8	4·4	7	·53	·13
September	83	95	75	20	27	63	7·4	5·3	8	·55	·14
October	81	91	74	17	26	73	7·8	7·8	11	·59	·14
November	79	87	71	16	26	76	7·4	5·2	9	·65	·13
December	76	85	69	16	27	74	5·9	3·1	6	·70	·13
Year... ...	82					63	6·0	37·1	55	29·60	

Mean highest temperature of year . .	106°	Absolute range of temperature . . .	51·3°
,, lowest ,, ,, . .	60°	Rainfall of wettest year (33 years) . .	95·3″ (1863)
,, annual range of temperature . .	46°	,, driest ,, ,, . . .	17·1″ (1845)
Highest recorded reading (12 years) . .	107·9° (1876, 1881)	Rainy days in wettest year (11 years) . ,	70 (1877)
Lowest ,, ,, ,, . .	55·6° (1884)	,, ,, driest ,, ,, . .	31 (1876)

CEYLON.

17. Colombo—Elevation 40 feet.

—	Temperature. Mean.	Temperature. Mean Max.	Temperature. Mean Min.	M. Range. Daily.	M. Range. Month.	Hum. Mean.	Cloud. Mean.	Rainfall. Ins.	Rainfall. Days.	Barometer. Mean.	Barometer. Daily Range.
January	79	86	72	14	21	74	4·9	3·0	6	29·88	·12
February	80	87	73	14	22	73	4·2	1·7	4	·88	·13
March	82	88	75	13	18	76	4·7	5·5	9	·87	·13
April	83	89	77	12	18	77	5·6	8·8	13	·82	·12
May	83	87	78	9	18	79	6·8	13·2	20	·81	·10
June	82	85	78	7	14	81	7·6	8·2	17	·82	·08
July	81	85	77	8	14	80	6·8	5·5	12	·83	·08
August	81	84	77	7	13	80	7·0	4·5	13	·84	·09
September	81	85	77	8	13	80	6·9	4·9	14	·86	·11
October	81	85	76	9	15	80	6·8	12·9	21	·86	·11
November	80	85	74	11	16	79	6·2	12·7	17	·86	·11
December	80	85	73	12	19	76	5·9	6·4	13	·87	·12
Year	81					78	6·1	87·3	159	29·85	

Mean highest temperature of year . .	93°	Absolute range of temperature . . .	30°
,, lowest ,, ,, . .	68°	Rainfall of wettest year (17 years) . .	139·7″ (1878)
,, annual range of temperature . .	25°	,, driest ,, ,, . . .	57·0″ (1874)
Highest recorded reading (12 years) . .	95·8° (1885)	Rainy days in wettest year (12 years) . .	195 (1885)
Lowest ,, ,, ,, . .	65·8° (1880)	,, ,, driest ,, ,, . .	125 (1876)

LOWER BURMA.

18. Rangoon—Elevation 41 feet.

—	Temperature.					Hum.	Cloud.	Rainfall.		Barometer.	
	Mean.	Mean Max.	Mean Min.	M. Range. Daily.	M. Range. Month.	Mean.	Mean.	Ins.	Days.	Mean.	Daily Range.
January	75	88	64	24	35	66	2·4	0·2	1	20·96	·13
February	77	93	65	28	38	62	2·2	0·1	1	·91	·14
March	81	97	71	26	37	64	2·2	0·1	...	·87	·15
April	84	98	76	22	31	68	3·6	1·8	4	·80	·15
May	83	93	77	16	27	76	6·5	10·9	16	·75	·12
June	79	86	77	9	18	88	8·8	18·4	28	·73	·09
July	78	85	76	9	16	90	9·0	21·3	29	·73	·08
August	78	85	76	9	16	91	9·0	18·6	27	·75	·09
September	78	85	76	9	16	89	8·3	16·0	26	·79	·11
October	80	88	76	12	18	85	6·2	8·1	14	·84	·12
November	78	87	73	14	24	80	4·5	3·4	6	·89	·11
December	76	87	68	19	29	74	3·2	0·1	1	·94	·12
Year	79					78	5·5	99·0	153	29·83	

Mean highest temperature of year . .	104°	
,, lowest ,, ,, . . .	58°	
,, annual range of temperature . .	46°	
Highest recorded reading (11 years) . .	106·7°	(1877)
Lowest ,, ,, ,, . .	55·7°	(1883)
Absolute range of temperature . . .	51°	
Rainfall of wettest year (17 years) . .	143·4″	(1871)
,, driest ,, ,, . .	69·1″	(1874)
Rainy days in wettest year (10 years) .	161	(1880, 1882)
,, ,, driest ,, ,, . .	132	(1878)

Of the climates of Ceylon and Burma it is impossible to say much here. The former has an extremely uniform island or 'humid marine' climate (*v.* table 17), whilst that of Lower Burma (*v.* table 18) resembles the climate of the West coast of India and that of Upper Burma approximates to the climate of Assam. There are, however, many important exceptions. There is promise of several excellent sites for hill stations among the Shan hills on the Burma-Siam frontier. Memyo is already occupied, and Byingyi, at an altitude of about 6,000 feet on a spur of the Shan hills, has been favourably reported on.

The above can only be regarded as a very brief summary of the more important of the climates of India, but it will serve to give the student or the newly-arrived medical officer some idea of the wonderful variety of climates afforded by the Indian Empire. For many districts and localities special hand-books have been written by former medical officers, civilians, and others, of which the name and other particulars are obtainable locally. There is a great want in many places of up-to-date and easily accessible information* regarding the local climate, diseases, customs, ethnography and other points of value to the hygienist, and it is extremely desirable that a complete and authoritative series of manuals, containing the latest obtainable information relating directly or indirectly to the science and art of hygiene, should be compiled by selected medical officers and published officially for the use of all concerned with the medical and sanitary work of the various districts.

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* The *District Manuals* which are written and published officially for many places are most useful, and should be studied by every medical officer, subordinate or otherwise, when appointed to a district; but the special information required is often absent, scanty, or quite out of date. The Madras District Manuals are now undergoing revision. Some are of a most unwieldy size and not so useful to the medical officer as the original topographical hand-books published many years ago. *V.* also many papers in the transactions of the Bombay Med. Phys. Soc., the Madras Journ. of Med. Sci., Census Reports, etc.

END OF VOL. I.

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(NOTE.—To Student.—*If the word looked for is not present as a separate heading, refer to the chief heading of the subject:* e.g., *for 'constant' method of water supply, see* WATER, *etc.*)

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